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BARK DISEASES OF CITRUS TREES IN CALIFORNIA

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BARK DISEASES OF CITRUS TREES IN CALIFORNIA*

HOWARD S. FAWCETT

INTRODUCTION

This publication is a revision and abridgment of Bulletin 360 brought up-to-date and supplemented by the addition of decorticosis (shell bark) and several other bark and gum diseases.

Its aim is to bring together the information now at hand regarding the bark diseases, including the various major and minor forms of gumming in Citrus trees under the conditions in California. Special emphasis is given to contributing conditions and to methods of prevention and treatment. A considerable amount of investigational data not heretofore published is included. The results of investigations in other phases of some of these diseases have been published elsewhere.[1] These phases will therefore receive only brief treatment here. It is necessary, however, to duplicate in part the descriptions of the diseases and a small number of other data.

Previous investigators had come to the conclusion that gum diseases of Citrus trees in California originated independently of microorganisms.[2] It was held that these diseases were largely autogenous in their nature, and frequently induced through the effects of certain climatic or soil conditions alone. It now appears evident that the environmental conditions cannot by themselves initiate the severe forms of gummosis in Citrus trees earlier attributed to them, although certain conditions are found to play (as they do in most parasitic diseases) an important role as contributing factors which favor infection and invasion of the host by the casual parasites.

The investigational work on which the greater part of this bulletin is based was begun in February, 1912, under the direction of the State Commission of Horticulture and continued after October, 1913, at the Citrus Experiment Station of the University of California.

* Paper No. 129, University of California, Graduate School of Tropical Agriculture and Citrus Experiment Station, Riverside, California.

[1] Fawcett, H. S., Jour. Agri. Res. 24:191–236. 1923.

[2] Smith, R. E., and Butler, O. Gum disease of citrus trees in California. Calif. Agr. Exp. Sta. Bull. 200:235–272, 1908.

Acknowledgment of the assistance rendered during this investigation has been given elsewhere.[3]

The names of species and varieties of Citrus used will be as follows: common lemon, *Citrus limonia* Osbeck; rough lemon, a horticultural variety of *C. limonia* Osbeck; sweet orange, *C. sinensis* Osbeck; sour orange, *C. Aurantium* L.; citron, *C. medica* Linn.; trifoliate orange, *Poncirus trifoliata* Raf.;[4] grapefruit,[5] *C. maxima* (Burm) Merrill, (*C. grandis* Osbeck). The word lemon, when used alone will refer to the common lemon, and the word orange to the sweet orange.

PYTHIACYSTIS (BROWN ROT) GUMMOSIS

HISTORY

A destructive form of gum disease similar to Pythiacystis gummosis first attracted serious attention in the Azores about 1834. A similar gum disease appeared in Italy as early as 1863; in Portugal, 1865; in Australia, 1867; in Spain, 1871; in the United States, 1875; and in most other Citrus regions before the year 1890. See accounts and references by Savastano,[6] Swingle and Webber,[7] Butler,[8] and Fawcett.[9]

In the early history of Citrus growing in California there appears to be no record of the occurrence of gum diseases until about 1875.[10] Not long afterwards they became an important hindrance to commercial Citrus culture, as is evidenced by the horticultural literature of the time.

A committee of growers appointed to examine the condition of Citrus orchards, stated in 1878[11] that at that time few localities were free from gum disease, which this committee believed was caused

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[3] Fawcett, H. S., Two fungi as casual agents in gummosis of lemon trees in California. Mo. Bull. Calif. State Comm. of Horticulture, 2:601–617, 1913.

[4] Swingle, W. T. "Citrus," *in* Bailey, L. H., Standard Cyclopedia of Horticulture, 2:270–785, New York, 1914.

[5] Merrill, E. D., and Lee, H. A., A consideration of the species *Citrus maxima* (Burm) Merrill. Am. Jour. Bot. 11:382–384. 1924.

[6] "Gummosi degli agrumi," **in** Patologia arborea applicata 127–141. Napoli, 1910.

[7] The principal diseases of Citrus fruits in Florida. U. S. Dept. Agr. Div. Veg. Phys. & Path. Bull. 8:1–42, 1896.

[8] A Study on Gummosis of Prunus and Citrus, Ann. Bot. 25:107–153, 1911.

[9] Gummosis of Citrus, Jour. of Agr. Research. Vol. 24: 191–236, 1923.

[10] Mills, J. W., Citrus fruit culture. Calif. Agr. Exp. Station, Bull. 138:1–46, 1902.

[11] Southern Calif. Horticulturist, 1:115, 1878.

by excessive irrigation and unsuitable cultivation. The orchards most heavily flooded with irrigation water, especially on heavy soils, were found worst affected. The application of manure immediately around the trees was also reported as tending to promote the disease. Lemon roots were found to be more susceptible than orange roots, and in a discussion which followed this report much objection is expressed to lemon and Chinese lemon stock as compared with sweet orange. Light soils were thought by many to be better adapted than heavy soils for orange culture since orchards on light soils were healthy while those on heavy soils were rapidly dying out, presumably from gum disease.

Irrigation by flooding was a common practice at that time and later[12] it was stated as a settled fact that the lemon (on lemon roots) is peculiarly sensitive to moisture and easily begins to rot if water is left standing around it. In the following year the statement was made in the same publication[13] that gum disease was induced by mid-summer irrigation and that lemon trees on their own roots were dying rapidly. In 1882 a leading nurseryman[14] regarded gum disease as the only trouble of importance.

Of the four Citrus stocks commonly used at that time (sweet orange, lemon, lime and citron) the lemon and the lime were stated by Garey to be the most fatally affected with this disease. He advises the use of the sweet-orange stock but says nothing of the sour orange which was introduced at a later date. Garey's description of the disease and his reference to the differences in susceptibility of varieties indicate that the type of disease spoken of was Pythiacystis gummosis. Because of the suceptibility of the lemon the growers gradually discovered that other stocks must be used. The universal verdict according to Holt[15] in 1892 was that lemons should not be grown on their own roots.

Sweet orange stock though much less susceptible than lemon was also frequently affected with gummosis. This fact drew attention to the sour-orange stock which had been used successfully in southern Europe and in Florida to replace trees affected with mal di gomma. This resistant stock only gradually came into use as a preventive of gum disease in California. Cutter[16] in 1892 stated that his attention was first called to the value of the sour-orange as superior to sweet

[12] Southern California Horticulturist, 1:314–315, 1878.

[13] Southern California Horticulturist, 2:83–86, 1879.

[14] Garey, Thomas A., Orange culture in California, 227, pp, San Francisco, 1882.

[15] Holt, L. M., "Lemon culture for profit," Proc. Calif. Pom. Soc., 1892.

[16] Cutter, J. E., Proc. Calif. Pom. Soc. 1892

in its resistance to gum disease in 1885. The following year the firm of Twogood, Edwards and Cutter of Riverside, received the first shipment of sour-orange trees from Florida for commercial purposes; although a few trees had been grown from Florida seeds for test by others before this time.

In the light of our present knowledge of varietal susceptibility of Citrus to gum diseases and of the part played by heavy soils and by excessive irrigation (especially flooding on heavy soils), the failure in growth on lemon stocks, and the dying of trees on heavy soils, but not on lighter soils would now appear to have been due to the presence and attack of gum disease organisms, especially *Pythiacystis citropththora* Smith and Smith.

The early discontinuance of the use of lemon, lime and citron as stocks, and the adoption of the orange as a general stock for all varieties appears to have been largely brought about by this one disease. Sour-orange stocks were introduced from Florida later, as previously indicated, for the purpose of combating this disease on heavy soils, but this stock has not been widely used in California until recent years.

SYMPTOMS

Pythiacystis or brown rot gummosis with its associated rot of the fruit[17] is probably the most widespread and destructive of the gum diseases. On the lemon (the most susceptible variety) patches of bark on the trunk are killed and often large quantities of gum are exuded (figs. 1 and 2*a*). Infection usually starts at the base of the trunk or on the crown roots and works rapidly upward, downward, and laterally. The bark is killed (not as in cases of psorosis and shellbark, merely in the outer cortical layers) but entirely through to the wood, thus including the cambium. A thin layer of wood tissue only about $\frac{1}{12}$ of an inch thick is visibly affected unless secondary organisms enter. The bark above the soil is not softened as it is in the early stages of Botrytis gummosis but remains firm and intact until drying causes it to shrink and crack longitudinally (fig. 2*b*). Below the surface of the soil secondary organisms frequently set up fermentation and moist decay. On the bark of old orange trees and other partially resistant varieties often the progress of the disease is soon arrested and the lesions tend to become self limited. The loss of large patches of bark is followed by a gradual yellowing and dropping of leaves on the branches leading out from the portion of the trunk affected.

[17] Smith, R. E., and others, The brown rot of the lemon. Calif. Agr. Exp. Sta. Bull. 190:1–72, 1907.

Although these are the main characteristics of the disease as seen on superficial examination, there are many special features which appear when more careful study is given to its development under various conditions. In the earlier stages of the disease the exuding gum is usually the only external symptom (fig. 2*a*). By lightly scraping the bark at this time the margin between the sound and invaded tissue is shown indefinitely, and only by the gradual shading of the normal green color into a drab. The bark is not softened but remains firm and only after a considerable time does it shrink and crack longitudinally (fig. 2*b*).

On healthy, rapidly growing lemon trees the area of killed and darkened bark, which is elliptical or irregular in outline, is usually 5 to 10 inches in vertical length and half that in width, when the gum first becomes apparent. By this time the fungus has been invading the tissue usually for a period of from 2 to 4 months. The removal of the bark at this time will show that the outer margin of the invaded zone in the inner tissues is about coëxtensive with that seen on the surface. The upward and downward extension from the point of infection is usually many times greater than the lateral extension.

In an irregular zone or band surrounding an actively invaded area, the cambium layer shows an influence extending from the margins of the dead bark. There is a production of clear, watery gum which seems to originate in the region of the embryonic wood among the live cells without any apparent fermentation or decay. This region, not yet darkened, outside the invaded portion, will be spoken of in this paper as the "outer gummous zone" (fig. 3*b*). It may in time extend considerable distances upward and downward and small distances laterally from the margin of the invaded zone (fig. 3*b*). It has been traced for 2 and 3 feet upward. The extent of this outer gummous zone varies with the age and rapidity of development of the disease lesion, the condition of the tree, etc.

The inner surface of the bark in the invaded zone in a lesion of considerable size, varies in color from mineral brown to burnt umber or fawn[18] and the same discolorations will be found on the surface of the wood just at or beneath the cambium (fig. 3*b*). The discoloration does not extend far (usually only $\frac{1}{10}$ to $\frac{1}{5}$ of an inch) into the woody layers. The cambium region in the gummous zone is chamois to yellow ochre in color, gradually fading at the margins into the normal color of the sound woody surface.

[18] Ridgway, Robert, Color standards and color nomenclature, 43 pp., Washington, D. C., 1912.

Frequently, when the bark is irregular in contour, gum pockets from 1 to 2 inches in length will be formed. The gum accumulates near the cambium and by pressure separates the bark from the wood at certain places, forming definite pockets. The pressure is usually relieved by a break in the bark before the pockets become large. A few deeper gum pockets of considerable size have also been found,

Fig. 1.—Pythiacystis or brown-rot gummosis on lemon trunk. The tree is completely girdled, the dead bark resulting from several infections starting near the soil surface. The ridges of exuded gum are characteristic.

situated in the outer gummous zone beneath layers of wood ⅛ to ¼ of an inch in thickness, showing accumulations of gum under pressure. The gum, which is watery and clear when first formed, hardens as it comes to the surface, apparently through loss of water, and finally becomes brittle. On the surface, the hardened gum is usually mahogany to chestnut in color.[18] The gum accumulates on the surface in long narrow ridges (figs. 1 and 2*a*) or in oval masses, or runs down and collects in masses on the soil, according to the rapidity of its formation and the dryness of the air. During periods of heavy dews and rains it gradually dissolves and disappears. The invading hyphae frequently die out rapidly behind the marginal fringe of advance, and quite often they die out completely over a part or all of this outer margin, so that the progress of the disease is checked or entirely arrested. Such cases are often found among trees having some power of resistance, especially among orange and grapefruit trees; or when the weather becomes unfavorable to the parasite after infection.

In trees on which the disease has been present for a long time, the dead bark over the invaded portions dries, shrinks and cracks. The larger cracks are mostly vertical, the smaller horizontal (fig. 2*b*). A thin layer of the wood immediately under the invaded bark will usually be found to be infiltrated with hardened reddish-brown gum which protects the under layers from rapid drying and to a considerable extent against the entrance of wood rotting fungi.

On old sweet-orange trees, the invaded areas are usually less extensive and more restricted laterally than on the common lemon. There is usually less gum than on the lemon. In the orange there is a greater tendency for the invading fungus to die out and for the invaded area to become self-limited than in the lemon. Frequently the invaded areas on old sweet-orange trunks extend upward from the soil surface as narrow tongues of killed bark. On younger orange trees and frequently on older ones growing vigorously on heavy clay soils the disease may assume much the same characteristics as it does on the common lemon.

INVESTIGATIONS INTO THE NATURE AND CAUSE OF THE DISEASE

Investigations begun in 1912 by the author[19] have led to the discovery that the disease is infectious and that the causal agent is a soil inhabiting "water mold," *Pythiacystis citrophthora*, the same fungus which was previously described as causing brown rot of lemon

[18] Ridgway, Robert, Color standards and color nomenclature, 43 pp., Washington, D. C., 1912.

[19] Faweett, H. S., Two Fungi as causal agents in Gummosis of lemon trees in California. Calif. State Comm. of Hort. Mo. Bull. 2:601–617, 1913.

fruits.[20] The relation of this fungus to the disease was discovered as a result of a series of experiments as follows:

1. Inoculation into sound trees with bits of diseased tissue transmitted the disease with all its characteristic symptoms (fig. 2). It was found, however, that only the diseased tissue from the marginal fringe of the killed bark of active lesions was capable of transmitting

Fig. 2.—Pythiacystis of brown rot gummosis on lemon tree. Produced by inoculation with diseased bark tissue

(*a*) Tree inoculated February 27, 1912, and photographed April 24, 1912. The large amount of exuded gum indicates the rapid development of a gummosis lesion. A majority of the trees in this same orchard had the same over growths at the union of stock and scion as observed in this illustration.

(*b*) Same view as (*a*) on May 24, 1913, 15 months after inoculation. The gum first formed has been dissolved by winter rains, and the dead bark has dried and shrunken. Gum was exuding (farther around) at this time.

the disease. Tissue from places away from this margin toward the center of large lesions or from the outer gummous zone was incapable of inducing gummosis.

2. Culture tests made from pieces of bark from various places within and beyond the killed portion of the lesions showed that

[20] Smith, R. E., and others, The Brown rot of the lemon, Calif. Agr. Exp. Sta. Bull. **190**:1–72, 1907.

Pythiacystis citrophthora was alive only at the marginal fringe of what was subsequently called the invaded zone. This fungus usually could not be isolated from the central portion of the invaded zone and it was never found in the outer gummous zone itself far from the margin of the visibly killed area. Isolations of this fungus were made at least 109 times from gummosis trees representing 30 different orchards in 10 different counties of California extending from San Diego on the south to Butte county on the north. It was isolated also from one locality in Arizona.

3. Inoculations were made into bark of sound trees with pure cultures of this fungus and the disease was induced with all its characteristic symptoms (figs. 3 and 4a). Many repetitions gave the same results. Inoculations with large numbers of other fungi and bacteria found in the older portions of the invaded zone failed to cause the disease. The reason for the fact that only diseased tissue from the marginal fringe of the invaded zone was capable of transmitting the disease was now revealed. In this portion only does the causal organism *Pythiacystis citrophthora* usually remain alive.

4. The same fungus was re-isolated 40 different times from 20 of the cases of gummosis produced by inoculation and again found to be alive only at the outer margin of the invaded zones, just as in the naturally occurring cases previously mentioned. The time elapsing between inoculation and re-isolation was from 1 to 12 months in different tests, and the fungus was recovered at distances of 20 inches or more from the original point of inoculation. One strain of this fungus isolated from a diseased tree at Whittier was inoculated into and re-isolated from three different trees in succession during a period of 3 years from 1912 to 1915. During this time the fungus lived in the bark of the three trees for periods of 5, 11, and 6 months respectively and between these periods in cultures for 2, 2, and 10 months respectively. Transfers from the original culture were kept alive for more than 8 years on cornmeal agar medium and were capable of producing brown rot of lemon fruits when tested in 1921.

5. Inoculations were made also with bits of lemon fruits affected with brown rot and with the fungus *Pythiacystis citrophthora* isolated from diseased fruits, with the same results as those obtained by the use of bits of diseased bark or cultures isolated therefrom. This experiment served to show that the fungus previously known to cause brown rot of lemon fruits and the one capable of inducing this type of gummosis were identical. The detailed experiments on which these statements are based will be found elsewhere.[21]

[21] Gummosis of Citrus. Jour. of Agr. Res. 24:191–236, 1923.

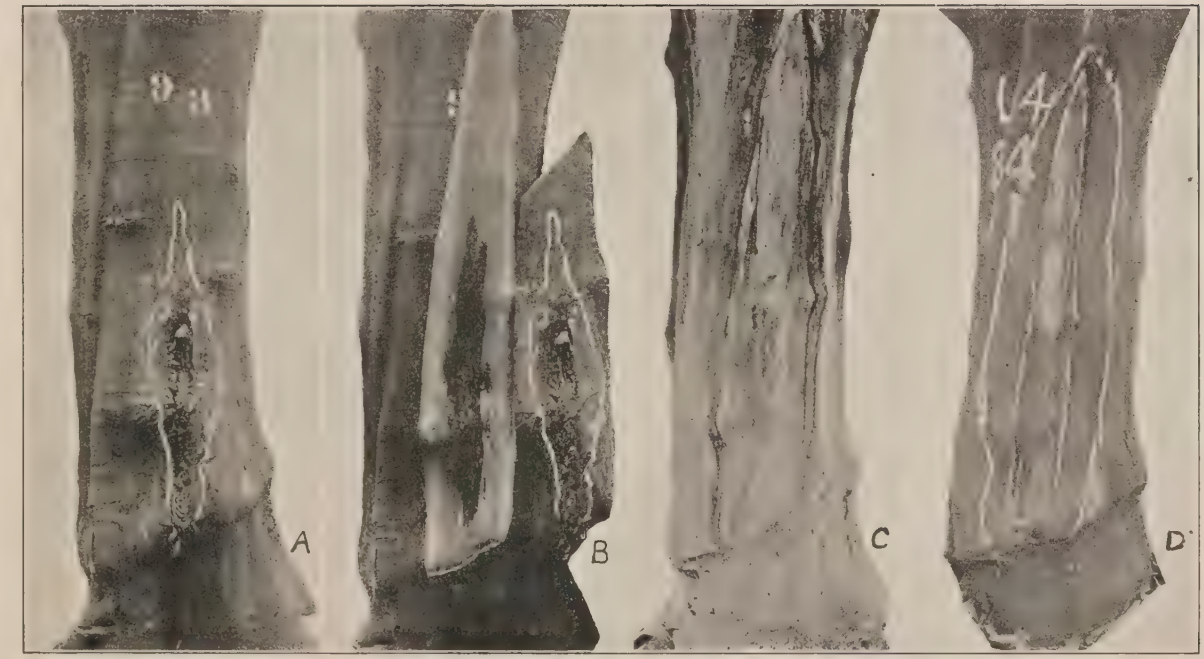

Fig. 3.—Pythiacystis or brown-rot gummosis on lemon tree. Inoculated November 23, 1912, with pure culture of *Pythiacystis citrophthora*.

(*a*) Extent of invaded portion (inside of chalk line) and gum formation on June 6, 1913. The fungus was isolated from several places near chalk line on this date. (*b*) Same tree after bark was cut, showing invaded zone (black) and a part of the outer gummous zone, which extended upward and downward under live bark. (*c*) Same tree in September, 1914, showing a new bark pushing in over wound. (*d*) Same tree in June, 1920, showing increase in new bark covering edges of original wound.

RESISTANCE OF DIFFERENT SPECIES AND VARIETIES

Among the Citrus species and varieties that have been tested the common lemon has the lowest resistance to Pythiacystis gummosis, and the sour orange the highest. The sour orange usually is so resistant to *Pythiacystis* attack that even when the most favorable conditions are given by inoculation in wounds, there is only a slight gumming with rapid healing of the wounded tissue and with total failure to produce a diseased lesion. The sour orange is also highly resistant to all other infectious gum diseases of importance. Mere gum formation, however, may be induced by suitable stimuli in sour orange as well as other species and varieties. Of the forms which have been most used for stocks in California, the trifoliate orange probably stands next to the sour orange in resistance and the sweet orange next to the common lemon in susceptibility, with the grapefruit and the rough lemon standing between these two. Because these stocks are grown from seed there is a possibility of variation in resistance within each variety due to differences between strains and observations have suggested that such variation actually exists. The following observations indicate the relative resistance of some of the common varieties.

A block of 5000 sweet-orange seedlings about two and one-half years old, growing in nursery rows on medium heavy clay loam soil, had been planted adjacent to a block of 15,000 sour-orange seedlings of the same age and receiving the same care. All the trees had been irrigated rather frequently and heavily. On October 21, 1914, four representative rows of sweet-orange trees showed the following percentage of infection:

Row	Number of trees in row	Number of affected trees	Percentage affected
1	222	52	23
2	213	73	34
3	212	63	29
4	180	53	29
Total	827	241	Average 29

On some trees only a small lesion was evident with much gum exuding, on others the bark was killed to a distance of 6 to 12 inches above the soil, with an abundance of gum, and still other trees were dead. Some trees showed a strong tendency to form ridges of callous tissue

along the edges of the dead strips of bark. A thorough search in the block of sour-orange trees failed to reveal a single affected tree.

Differences in resistance are indicated further by an estimate made by W. M. Mertz, in a nursery of Citrus seedlings about two years old, growing at the Citrus Experiment Station. The following is the percentage of gum disease (probably Pythiacystis gummosis) which was recorded:

Species	Number of trees	Per cent with gummosis
Citrus Aurantium (sour orange)	1000	0.3
Poncirus trifoliata (trifoliate orange)	1000	1.0
Citrus maxima (grapefruit)	1000	2.5
Citrus sinensis (sweet orange)	2000	10.00

CONDITIONS FACILITATING INFECTION AND DEVELOPMENT OF THE DISEASE

A study of the external conditions under which Pythiacystis gummosis is most likely to become severe, taken in conjunction with experiments with the fungus, indicates that the important factors are: (1) abundant moisture in the soil in contact with the bark over a sufficiently long period, (2) favorable soil and air temperature, and (3) wounds or other injuries to the bark.

Injuries, however, although aids to infection, are not necessary if the two first-named conditions are simultaneously fulfilled. Injuries, especially below the soil surface, aside from inducing infection more readily when the conditions of moisture and temperature are suitable, may even aid in bringing about infection where the soil moisture is not excessive by conveying the organism into the moist inner bark tissue where penetration can start without the addition of further moisture. Wounds or injuries, therefore, while not absolutely necessary for the entrance of the parasite when sufficient moisture is present are probably the only means of entrance when the moisture content of the soil immediately in contact with the bark surfaces is not favorable to infection.

Moisture.—The severe form of Pythiacystis gummosis is most frequently found in California on lemon trees where they are budded low on sweet-orange stocks which are growing on heavy soils and is especially prevalent in the coastal sections. In the light of what has been shown this is readily understood. Heavy clay soils, being much more retentive of moisture than lighter, more open soils, fur-

nish the means by which water films may remain adjacent to the bark for periods of time sufficient to permit infection by the parasite.

The great prevalence of fogs, and the comparatively slight fluctuations of temperature in the coastal sections also decrease the rate of evaporation in the soil adjacent to the trees that has become excessively wet during irrigation or rain. In the interior valleys even the same type of soil usually drys out more quickly after irrigations and rains. If the drying out is rapid there is not sufficient time for infection; if drying is slow, however, the time may be sufficient for the penetration of the fungous hyphae. The effect of a low bud union is mentioned later. The lemon bark above the union may be infected directly when the fungus has communication directly with it through excessively moist soil or by splashing of raindrops, especially when wounds are present. High budded lemon trees are less liable to the disease. If budded high on sweet-orange stocks they are more likely to escape, because this stock is somewhat more resistant than lemon. It is nevertheless susceptible to infection, especially under conditions highly favorable to the disease. If budded high on sour-orange stock, however, there is practically no danger of the disease even under bad water conditions, because of the great resistance of this stock.

Temperature.—Within certain limits, temperature appears to be another important factor, especially in the growth of the fungus and its formation of spores and in the infection of the host as a result of the germination of these spores. As has been previously shown,[22] a temperature somewhere near 25° C. (77° F.) appears to be about the optimum for a sustained growth of the fungous hyphae in cultures, and very little growth takes place above 30° C. (86° F.). If as seems probable similar relations hold for the growth of the fungus in the bark, we have an explanation of the fact that the disease progresses slowly during hot periods, and also of the fact that its progress is sometimes completely checked, the fungus being killed out in many instances. This occurs especially in the interior valleys, in the case of parts of lesions entirely above the soil surface. Here the temperature of the bark frequently reaches many degrees above the death point of the fungus. Recent experiments[23] have shown that a temperature of 115° F. for one minute is sufficient to kill the spores of this fungus on infected fruits and temperatures much lower than this for greater lengths of time will undoubtedly have the same effect.

[22] Fawcett, H. S., The temperature relations of growth in certain parasitic fungi, Univ. Calif. Publ. Agr. Sci., 4:183–232, 1921.

[23] Fawcett, H. S., Calif. Citrograph, 7:233 and 254, May, 1922.

Corroborating this view is the observation that the rapid enlargement of invaded areas usually continues much later in the year or may proceed throughout the whole year in the cooler coastal sections, while the activity and progress of the disease are usually limited to the winter, spring and early summer in the hotter interior sections.

Other Conditions.—A further condition which contributes to the chance of infection in the orchard is that of deep planting, and the accumulation of soil next to the trunk of the trees. This brings a greater surface of the bark in contact with the soil, and the bud union, if low, may be buried. The bark over the union between stock and scion is usually especially susceptible to infection, probably because of frequent irregularities of growth, suckering, etc. The practice of loosening the soil by digging about the base of the tree, if no injuries are produced, probably helps to prevent infection by hastening the drying out of the soil. This practice may, on the other hand, if carelessly performed, result in injuries to the bark and aid in the entrance of the organism or actually introduce it into the inner bark tissues on bits of soil. Any agency such as gophers, field mice, or rabbits, or tools used in orchard operations that produce injuries to the bark, may contribute to the ease of infection by the parasite. Infection, however, appears to take place frequently through the sound uninjured bark.

The following is a concrete example of a set of conditions that resulted in a serious outbreak in a 5-acre 6-year-old lemon orchard at Whittier in 1914, on medium heavy clay soil.

The season had been one of unusually heavy rainfall. A volunteer crop of barley was cut while green in March and thrown around the trees in contact with their trunks. This operation was followed by heavy rains and cloudy days. During the following May 90 trees with brown-rot gummosis in various stages were discovered. The lesions appeared to have started at various places below and above the surface of the soil. Some of those above the surface had started at places where water sprouts had been broken off, but many appeared to have started in sound, uninjured bark. The barley piled around the trunks had undoubtedly aided in retaining films of water for a sufficient time to permit germination of the spores and the penetration of the hyphae. All the diseased trees were successfully treated under my direction by the methods recommended here.

FUSARIUM AS AN ACCESSORY IN THE DEVELOPMENT OF PYTHIACYSTIS GUMMOSIS

During the examination of a large number of naturally occurring cases of Phythiacystis gummosis it was noticed that a species of Fusarium frequently accompanied and was closely associated with *P. citrophthora* in the diseased tissue. The question arose as to whether the Fusarium played any part in the development or the severity of the disease.

Fusarium has been mentioned frequently in the literature as having some possible relation to certain types of gum disease. Briosi[24] and McAlpine[25] concluded that *Fusarium limoni* Briosi played an important part in mal di gomma in Italy and in Australia. Earle and Rogers[26] though not able to produce gummosis by inoculation with Fusarium, believed that under certain conditions it was probably a factor in a certain type of gum disease in Cuba. I also had previously found species of Fusarium repeatedly associated with mal di gomma or footrot in Florida, but inoculations with them had given negative results.

Although the experiments made with this question in mind have been too few as yet to allow definite conclusions to be drawn, certain results have indicated that the severity of the disease is slightly increased by adding Fusarium along with *Pythiacystis citrophthora* at the time of inoculation. The characteristics of the disease, however, were the same as when the *Pythiacystis* was inserted alone, while inoculation with Fusarium alone failed to produce this type of gummosis. Fusarium inoculations caused only a slight killing of a narrow layer of tissue along the cut without gumming and later resulted in a cracking of outer layers of bark around the cut. Otherwise the effect was not different from that produced in the uninoculated cuts used as checks on the same trees.

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[24] Briosi, G., Intorno al mal di gomma degli agrumi (*Fusisporium limoni*, Briosi). Atti R. Acad. Lincei, Roma, ser. 3ª, vol. 2; Memoria della classe di science fisiche etc., pp. 485–496, 1878.

[25] McAlpine, D., Fungous diseases of Citrus trees in Australia and their treatment, Melbourne, p. 132, 1899.

[26] Earle, F. S., and Rogers, J. M., "Citrus diseases at San Pedro in 1915," *in* San Pedro, Isle of Pines, Citrus Path. Lab., Ann. Report 1:36–38, 1915.

METHODS OF CONTROL

Prevention.—The causative fungus usually infects the bark at or below the surface of the soil. The roots of a susceptible variety are more resistant than the bark of the trunk. As pointed out above, some of the principal conditions of infection are: (1) excessive wet soil in contact with the trunk, as a result of improper irrigation and drainage, or long periods of continuous rains; (2) deep planting, or soil piled up around the trunk, especially when it is highly retentive of moisture; (3) injuries to the bark at the base of the tree, especially in wet weather.

The methods which have been found effective and are now in common use in preventing infection brought about by these conditions, are those which follow:

The soil is pulled back from the base of the tree to expose the top of the first main roots and is left in a circular ridge to exclude irrigation waters from the depression next to the trunk. If the depression occasionally becomes filled up with water, the resulting condition is usually not so serious as when the soil is against the bark, because the water after a rain soon percolates into the soil. Under usual weather conditions in California, with most Citrus soils, the length of time that water would stand in such a depression is not sufficient to produce infection.

This pulling away of the soil is most important on the heavier clay soils. On looser sandy soils it is not so necessary.

As an additional means of prevention the bark at the base of the trunk is painted with Bordeaux paste or other non-injurious fungicide after pulling the soil away. (For results of extensive experiments in prevention see Bull. 360, Calif. Exp. Sta. 1923.)

A means of prevention especially on very heavy soils, is to use trees budded high, 1 to 2 feet or more, on resistant stocks, such as a good type of the sour-orange. The sour-orange stock is resistant, not only to Pythiacystis gummosis but also to psorosis and other gum diseases.

Treatment.—Even when careful attention is given to prevention, a few cases of Pythiacystis gummosis will often occur from time to time, especially with trees on susceptible stocks planted in heavy soils. The following method of treatment has been adopted as the result of much experimental work in which the coöperation of growers has been of great assistance.[27] The extent to which the bark is killed

[27] Fawcett, H. S., Calif., State Comm. of Hort. Mo. Bull. 2:601–617, 1913, and Prizer, J. A., Calif. State Comm. of Hort. Mo. Bull. 4:7–19, 1915.

through to the wood is first ascertained by scraping slightly. Then the brownish killed bark (invaded zone) is dissected out with a heavy knife, cutting through to the wood about ½ inch beyond the invaded zone on the sides and 1 to 2 inches beyond at the top and bottom in a manner similar to that shown in figure 4*b*. The cuts on the two sides are usually brought together above and below, making an acute angle. No attempt is made to cut beyond the outer gummous zone, since it has been shown that this zone does not contain the invading parasite. The live bark over this zone of gummous influence, not yet invaded by *Pythiacystis citrophthora*, will usually recover rapidly as

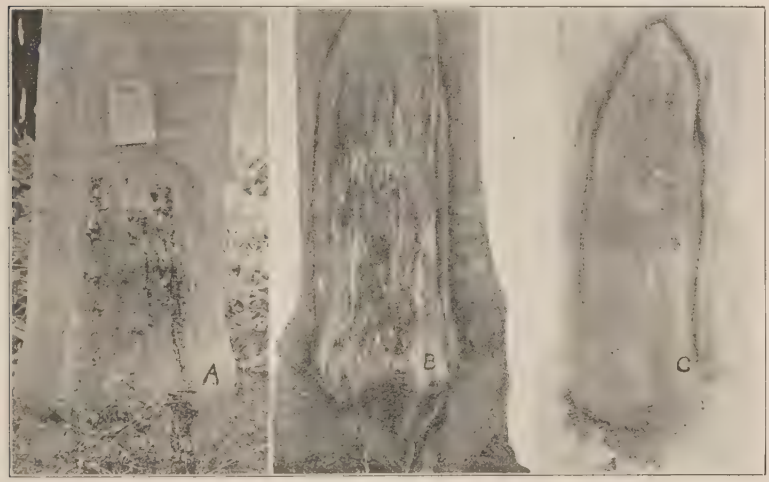

Fig. 4.—Method of cutting away diseased bark in treatment of a severe case of Pythiacystis gummosis.

(*a*) Result of inoculation with a bit of diseased bark on November 16, 1912. Photographed September 3, 1913. Invaded area 3×8.5 inches.

(*b*) Bark cut away September 3, 1913. Ready for painting with Bordeaux paste.

(*c*) Same tree on March 17, 1916 (3½ years later) showing growth at edges of wound and asphalt paint on exposed wood.

soon as the invaded portion has been removed and the further progress of the fungus has been stopped. These cut-out places and the entire trunk are then painted with Bordeaux paste (1 lb. copper sulphate and 2 lbs. rock lime to 1½ gallons of water) or some other suitable fungicide (see formulae under "Psorosis"). The fungicides other than Bordeaux paste which have been most generally used in California are coal tar products from which the lighter oils have been distilled such as Arrow Carbolineum and Avenarius Carbolineum.

Other safe fungicides of known composition are: mercuric chloride 1 gram to 1000 cc of 25 per cent denatured alcohol (⅛ ounce to one gallon) or mercuric cyanide of the same strength; emulsified cresol (liquor cresolis compositus USP) 10 per cent in water; or potassium permanganate crystals 1 per cent in water (one ounce in 3 quarts of water). The mercuric chloride and mercuric cyanide may be obtained as tablets or in crystalline form, the potassium permanganate and copper sulphate in crystalline form, the liquor cresolis compositus and carbolineums in liquid form. These are sold by drug stores, drug companies and spray dealers.

Before applying to the bark carbolineum or any other product the exact composition or effect of which is unknown, it should be tested on some leaves and twigs several days before it is to be used on the bark. If in two or three days it does not seriously injure the mature leaves or twigs it will probably be safe to apply to the bark. If, however, the leaves are severely burned, the product is usually not safe to use on the bark.

The elimination of the tissue invaded by the causative organism is the most important feature of the treatment, the purpose of the fungicide being to prevent reinfection, or to kill the organism in small bits of tissue left behind.

After treatment the gum usually continues to exude for some time at the edges of the cut-out areas. This is left undisturbed except to examine the edges of the cuts to ascertain whether any bark is being killed by further invasion of the fungus. The gum appears to act as a protective covering under which callous tissue is readily formed along the edges of the cuts. After these cut edges begin to heal, the exposed wood is painted with asphalt paint or other good covering (fig. 4*c*).

In cases where a large part of bark on the trunk has been killed by the rapid invasion of *Pythiacystis citrophthora*, so that the trunk is girdled or nearly so, bridge grafting[28] and inarching[29, 30, 31, 32] may often be resorted to in order to save the tree (fig. 5).

The advisability of this practice, in any particular instance, will depend upon the age and condition of the tree and other factors. A modification of the usual method of bridge grafting has been suc-

[28] Paddock, E. H., Bridge grafting on Citrus, Calif. State Comm. Hort. Mo. Bull. 81:72–73, 1919.

[29] Rundle, H. E., Inarching Citrus trees. Calif. Cultivator, 44:540–541, 1916.

[30] Hume, H. H., Citrus fruits and their culture, ed. 4, 196 pp., New York, 1911.

[31] Fawcett, H. S., Experiments in bridge grafting and inarching in connection with Gummosis of Citrus. Calif. Citrograph, 8:68 and 95, 1923.

[32] Hodgson, R. W., Saving the gophered Citrus tree, Calif. Agr. Exp. Sta. Cir. 273:1–20, 1924.

cessful with Citrus. Instead of a shoot or branch being grafted into the bark both above and below the injured portion, a sprout at or below the lower edge of the wound is allowed to grow. When of sufficient size the top part is cut off, bent over, and grafted into the bark above the diseased area (fig. 5*b*).

Fig. 5.—(*a*) Young lemon tree into which a sour-orange seedling ¼ inch in diameter had been inarched over a gummosis lesion about 2½ years before. The inarched seedling had increased to ¾ inch in diameter and had caused a ridge of growth above as shown alongside the white chalk mark.

(*b*) Old lemon tree showing gummosis lesion bridged by inarching sprouts from the base. About 5 years after inarching.

Another similar method of saving or aiding an injured tree is inarching, in which one or more small seedling trees are planted close to the trunk and the top grafted into the bark above the injury. Where quick relief is necessary and suitable sprouts cannot be stimulated, this method has proved beneficial (fig. 5*a*). (For details as to extensive experiments in treatment see Bull. 360, Calif. Agr. Exp. Sta.)

An example of what can be done in controlling Pythiacystis gummosis when it is treated promptly and with care, is furnished by a

five-acre lemon orchard at Whittier on clay loam soil, previously referred to, where conditions facilitating infection obtained. About 20 per cent of the six-year-old trees became infected after a period of heavy rains which followed the application of green, freshly cut barley about the trunks in March, 1914.

The lesions noticed in May varied in size from those just started to lesions extending one-half to two-thirds around the circumference

Fig. 6.—Showing a method formerly used in treating brown-rot gummosis by cutting vertical slits in the bark, one on each side of the diseased lesion and several down through the invaded area. This treatment appeared to be of some value for mild cases, but was useless for more severe outbreaks.

of the bark on the trunk. On May 25, 1914, the trees were treated by dissecting out all the brown killed bark (invaded zone) and cutting about ½ inch beyond this invaded zone on the sides and from 1 to 2 inches beyond at the top and bottom, as is shown in fig. 4*b*. The cuts on the two sides were usually brought together above and below, making an acute angle.

No attempt was made to cut beyond the outer gummosis zone of gummous influence, so that in most cases on larger lesions this zone probably extended into the remaining bark a considerable distance beyond the cuts. As has been pointed out in the description of the disease and elsewhere, the margin of the zone actually invaded by the causal fungus usually lags far behind the zone in which gum formation occurs. These cut-out places and the entire trunks were painted with Bordeaux paste (1 lb. copper sulfate and 2 lbs. rock lime to 1½ gallons water). In order to prevent further infection the soil was pulled back from the trunk as far as the top of the first main roots.

After treatment, the gum continued to exude in considerable quantities at the edges of the cut-out areas. This gum was left undisturbed except for examining the edges of the cuts to ascertain whether the bark was being killed further. The gum appeared to act as a protective covering under which callous tissue was soon seen to be forming rapidly along the edges of the cuts.

On June 22, 1914, about one month after treatment, an inspection showed only five trees with new areas of killed bark, all of which areas were on treated trees. On August 3, seven additional areas of killed bark were found, and on September 15, eight additional areas, all except two of which were on treated trees.

On March 29, 1915, a rapid healing was noted at all the cuts and no effect on the foliage could be detected. Three new lesions, all originating below the surface of the soil, were found.

On July 30, 1915, three trees which had lost bark from areas extending over two-thirds to three-fourths their trunk circumferences, were showing a slight yellowing of the foliage, but only on branches directly above the dissected areas. By March 6, 1916, however, only one tree showed any appreciable effect of the removal of bark and this was one from which about 120 square inches had been removed. The trunks of all the trees had been painted again with Bordeaux paste in the fall of 1915, and no new cases were found during the spring and summer of 1916.

The rapidity with which cut-out places of various sizes healed is indicated by table 2. These figures were obtained by measuring the areas in two directions and estimating the number of square inches

in each. While the figures are only approximate, they give a rough idea at least of the rate at which areas of different sizes on lemon trees of this age may be expected to close up with new bark tissue.

TABLE 2

Number of areas	Average size of original areas, May, 1914	Average size of same areas, June, 1916	Average size of same areas, April, 1921
	sq. in.	*sq. in.*	*sq. in.*
5	.5	0.0	0.0
3	1.0	.08	0.0
8	2.0	.97	0.0
4	3.0	1.2	0.0
10	4.0	2.7	0.6
2	5.0	3.5	0.5
5	6.0	3.7	0.0
4	7.0	2.5	0.9
7	8.0	4.0	0.6
5	10.0	4.2	1.0
2	11.0	8.0	2.0
5	12.0	9.8	3.2
3	16.0	11.3	5.0
5	22.0	17.0	5.6
4	35.0	27.0	7.5
3	40.0	22.0	15.0
7	50.0	42.5	25.0
4	75.5	55.0	23.7
5	105.6	69.0	39.6
1	130.0	80.0	60.0

It will be noted that all wounds less than 3 square inches in size when treated were closed, or insignificant, at the end of 2 years. Nearly all wounds less than 10 square inches in size when treated were closed in 7 years. Areas larger than 10 square inches were reduced to about one-half to two-thirds of their original size in 2 years and to about one-third to one-fourth their original size in 7 years.

MAL DI GOMMA, OR FOOT ROT

Mal di gomma, due to *Phytophthora terrestris* Sherbakoff,‡ is a gum disease with close relationships to Pythiacystis gummosis. Certain phases of the Pythiacystis gummosis occurring on, or near, the main roots of sweet-orange trees, are quite similar to those of mal di gomma or foot rot. For this reason, certain foot rot-like forms, due *to Pythiacystis citrophthora* in California, have previously been

‡ *Phytophthora terrestris* is by some authors considered to be the same as *P. parasitica.*

referred to as mal di gomma,[33, 34] Since the term mal di gomma was used in Florida to designate a common Florida gum disease, which is now known to be induced by *Phytophthora terrestris*, it is proposed to restrict its use (in this country at least) to the disease due to this fungus.

SYMPTOMS

This type of gum disease affects, for the most part, the bark on the lowest portion of the trunk and the upper portion of the highest main roots, mostly below the surface of the soil. Gum usually forms on the trunk of the tree above the soil. The inner bark and finally the wood underneath frequently develop a fetid odor.* The bark dies and breaks away in patches, leaving bare, dead areas, which spread in all directions, but mostly downward, on the main crown roots and laterally around the trunk (fig. 8). Trees thus affected bear heavy crops of fruit temporarily and the leaves become yellow.

HISTORY

This gum disease was first known as foot rot and attracted attention in Florida about the same time that Pythiacystis gummosis was noticed in California. Curtiss,[35] in 1888, reported that it appeared in 1876, although few people, he says, remember having observed it before 1880. That the disease was not important in Florida before that time is indicated by the fact that Bishop,[36] writing on Citrus culture in Florida in 1875, discusses a number of other diseases but does not mention this one.

In a book published in 1881, Moore,[37] who made extensive observation on Citrus culture in Florida, speaks of this disease under "foot rot" as having appeared in "late years" in Florida. In 1896 Swingle and Webber[38] stated that the disease was widely distributed in Florida and seemed to be gradually spreading.

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[33] Smith, R. E., and Butler, O., Gum disease of Citrus trees in California. Calif. Agr. Exp. Sta. Bull. 200:235–272, 1908.

[34] Fawcett, H. S., The known distribution of *Pythiacystis citrophthora*, and its probable relation to mal di gomma. Phytopathology, 5:66–67, 1915.

* The rotting of the wood, as well as the bark, and the accompanying fetid odor are believed to be due mainly to secondary organisms setting up fermentation and decay below the surface of the soil after the killing of the bark by the primary organism. While gum may be formed below as well as above the surface of the soil, it is dissolved readily by moisture and is usually less conspicuous below the soil surface. This disease, under California conditions, cannot be distinguished from certain phases of brown rot gummosis except by means of culture tests for isolating the causal organisms.

[35] Curtiss, Sore shin or gum disease. Fla. Agr. Exp. Sta. Bull. 2:27–42, 1888.

[36] Bishop, P. P., Proc. Am. Pomo. Soc., p. 48, 1875.

[37] Moore, T. W. Treaties and handbook of orange culture, New York, 1881.

[38] Swingle, W. T., and Webber, H. J., The principal diseases of Citrus fruits in Florida. U. S. D. A., Div. of Veg. Phys. and Path. Bull. 8:1–40, 1896.

INVESTIGATIONS

Only once has the causal fungus been isolated in California. This was from an orange tree at Lindsay in 1912. It was considered by the writer at that time to be only a peculiar strain of the brown rot fungus, *Pythiacystis citrophthora*, but was later identified by Sherbakoff as the same species which he had previously described.[39] This species, or a closely allied one, appears to be widely distributed, occurring in a number of countries. It was found on Citrus[40, 41] in Florida, Cuba and Argentine; on coconuts, tobacco and pineapples in Jamaica;[42] on tomatoes in Florida[39] and castor oil plants and Vinca in India.[43]

Many comparative inoculations, with *Pythiacystis citropthora*, the cause of brown rot gummosis, and *Phytophthora terrestris*, the cause of mal di gomma, were made under various conditions and the same type of lesion was produced by each fungus. There was an indication in some of the experiments that sweet-orange bark was more susceptible than lemon to *Phytophthora terrestris* while the reverse was generally true of the fungus of brown-rot gummosis. According to Hume,[44] in Florida the sweet orange is more susceptible to mal di gomma than the common lemon, and sour-orange is very resistant.

The relation of temperature to growth is somewhat different for the two fungi.[45] While the optimum temperature for sustained growth over a period of several days in the laboratory for *Pythiacystis citrophthora* is about 77° F. (25° C.), that for *Phytophthora terrestris* is about 86°F. (30°C.). It is of interest in this connection that the rainy season in California occurs during winter and spring, coincident with moderate temperatures, while the moist season in Florida occurs during the summer, coincident with much higher temperature.

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[39] Sherbakoff, C. D., Buckeye rot of tomato fruit. Phytopathology, 7:119–129, 1917.

[40] Fawcett, H. S., Pythiacystis and Phytophthora. Phytopathology, 10:397–399, 1920.

[41] Stevens, H. E., Florida Citrus diseases. Fla. Agr. Exp. Sta. Bull. 150:1–110, 1918.

[42] Ashby, S. F., Leaf-stalk rot caused by *Phytophthora parasitica*. In West Indian Bull. 18:70–73, 1920.

[43] Dastur, J. F., *Phytophthora parasitica* new species; a new disease of the castor oil plant. Mem. Dept. Agr. India, Bot. Ser., 5:177–231, 1913; *idem.*, Phytophthora on *Vinca rosea*. Mem. Dept. Agr. India, Bot. Ser., 8:233–242, 1916.

[44] Hume, H. H., Some Citrus troubles. Fla. Agr. Exp. Sta. Bull, 53:145–173, 1900.

[45] Fawcett, H. S., The temperature relations of growth in certain parasitic fungi. Univ. Calif. Publ. Agr. Sci., 4:183–232, 1921.

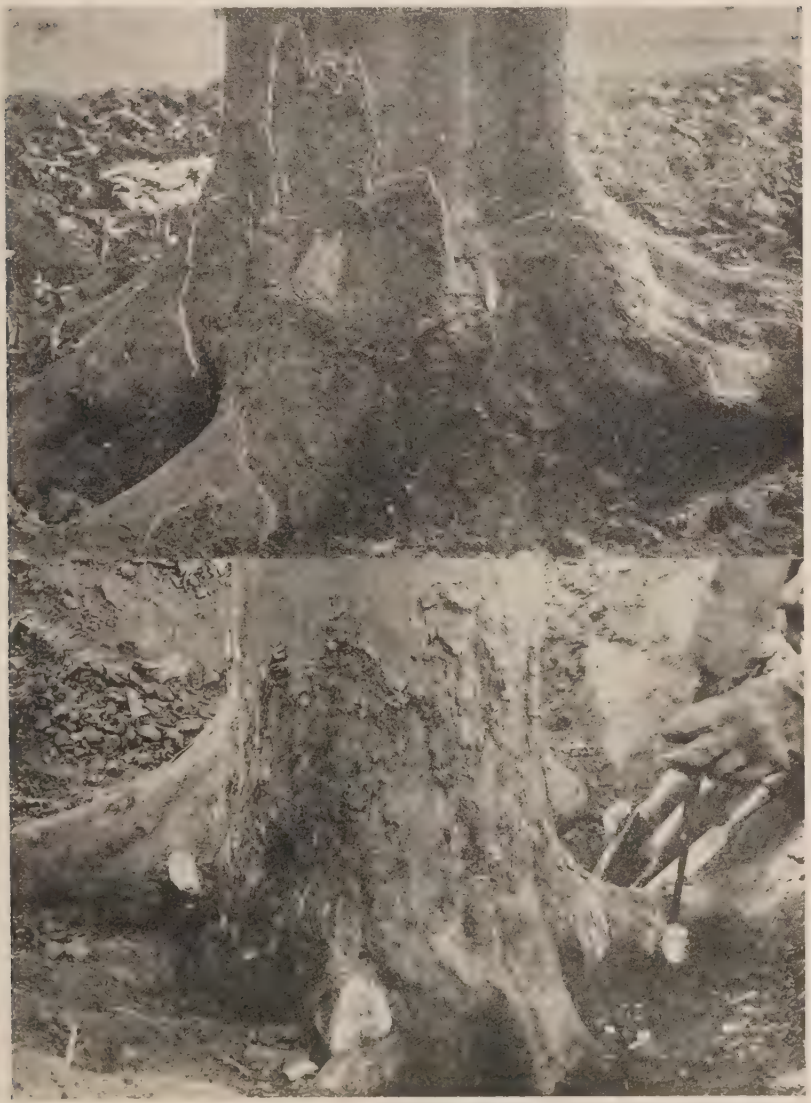

Fig. 7.—Mal di gomma or footrot. (*a*) On 40-year-old seedling orange trees. White lines indicate boundaries of killed bark. (*b*) Earth dug away and affected bark and roots being removed before applying Bordeaux paste.

CONTROL

The means of prevention and treatment of mal di gomma, are essentially the same as those for brown-rot gummosis, a certain form of which it so closely resembles that only laboratory examination can distinguish the two diseases. Care regarding excessive moisture in contact with the bark of the crown roots and the base of the trunk, care in keeping the soil away from the base of the tree and in avoiding injuries, the use of sour-orange stocks for new plantings, the use of fungicidal washes on the bark, are all useful in prevention. For detailed suggestions regarding prevention and treatment, see under brown-rot gummosis.

DRY ROOT ROT

A disease of the roots known as dry root rot is of considerable importance in California. Root diseases of the same general nature have also been described in other countries. This root rot has been designated by the term "dry" to distinguish it from the wet or disintegrating types of rot like that of Armillaria and certain phases of mal di gomma, etc. It is only in its later stages, however, that it is really a dry root rot.

Symptoms.—Decay of the bark and wood takes place on roots at and below the crown and usually below the surface of the soil. In the active stages of the decay, especially when it is starting, the bark is moist and if the soil is wet there may be a semi-mushy condition. This is not so pronounced or soft as in certain other root rots. Usually no gum is apparent, but occasionally a small amount is visible at the advancing edge of the active lesions. The disease is often associated with mal di gomma or Pythiacystis gummosis in which case considerable gum may be present.

Large or small lesions may occur on roots at little distance from the crown or the entire crown and base of main roots may be involved in varying degrees. It may start on the side of a tap root or on large lateral roots and later spread to the crown. The bark is at first soft, soggy and abnormally dark. When further decay sets in, it becomes dryer and crumbles away. Hard dead wood is found underneath. There is a tendency in some cases for the lesions to enlarge for a time and then become self-limited by a production of callus. Smaller lesions may be partially covered with new bark as time goes on. Unlike pure Pythiacystis gummosis or mal di gomma the wood

usually becomes affected for some distance inward. The wood becomes light brown, and remains firm as the dry root rot proceeds. This dry decay in the wood frequently involves a greater part of the woody cylinder of the root and consequently has a severe effect upon the tree. The symptoms above the ground are usually manifested in an open thin appearance of the tree, yellowing and dropping of foliage and frequently the setting of an unusually large crop of fruit. The effects are much the same as if the trees were gophered or had severe mal di gomma or Pythiacystis gummosis. The leaves may wilt suddenly and the entire foliage and twigs dry up in a few days or the tree may have a lingering, more gradual death in which it first becomes slowly defoliated.

Contributing conditions and probable cause.—The investigations of Barrett[46] in California have shown that fungous species of Fusarium are nearly constantly associated with dry root rot lesions. He states: "The fact that different species of Fusarium have been isolated from different cases of the disease occurring in different sections, would indicate that closely related types of dry root rot may be induced by several species of the genus Fusarium." I also have found Fusaria commonly in the dry root rot lesions. Inoculations by Barrett from pure cultures of Fusaria as well as from diseased tissue, have so far failed to reproduce the disease in its severe form. I have made similar inoculations with the same results. Only small lesions have resulted.

Some of the conditions thought to be important are excessive moisture, poor aeration, heavy soils and possibly injuries to the roots such as those due to larvae of Fuller's rose beetle, rodents, heavy fumigation with cyanide, etc. Excessive moisture at the base of the tree is probably one of the most important. The lack of aeration would naturally accompany or follow excessive moisture. Heavy soil while possibly a factor is not necessary to its occurrence. Some very severe cases have been found in sandy soil.

Control.—No thoroughly satisfactory method of control appears feasible for advanced stages of the dry root rot since the wood as well as the bark is affected. The method of cutting away only the diseased bark as in mal di gomma and Pythiacystis gummosis is not sufficient. If only certain roots are affected and the tap root and crown are still in good condition, these diseased roots should be cut out and destroyed. It may be advisable if a lesion is not too far advanced at the crown of a large tree to carefully cut some distance beyond the

[46] Barrett, J. T., Annual Rept. of Calif. Citrus Institute, 1919–20, p. 157, 1920.

visible margin of the dry decay in the wood as well as the bark. The wound should then be disinfected with mercuric cyanide or mercuric chloride (1 to 500) or Arrow carbolineum and a little later covered with thick asphalt paint or tar. Wounds made in cutting off large roots may be treated in the same manner. Preventive measures consist in keeping away excessive water, especially from the crown, providing good aeration and drainage, and avoiding injuries to the roots as far as possible. These precautions will also help in preventing Pythiacystis gummosis, mal di gomma and other troubles that depend to a considerable extent on the same contributing conditions. Under some conditions of very heavy soil a preventive Bordeaux wash applied to the base of the large roots and crown may also be useful.

ARMILLARIA ROOT ROT

This disease, known also as oak root fungus and fungus root rot, is troublesome in certain sections of California, especially in localities where affected oaks have been cut down and Citrus trees planted. The disease is due to a toadstool fungus, *Armillaria mellea*.

More or less gumming often accompanies this disease. It is, therefore, included under the gum diseases. The gum oozes out at or just above the base of the trunk, and might be confused with that due to some forms of gummosis. This disease is characterized by a decay of the roots, and of the bark and wood at the base of the tree, and by the formation of black strands on the roots and of fan-shaped, felted, white growths which crowd into the live bark. It is accompanied by a mushroom odor and by the development of toadstools of *Armillaria mellea* near the base of the tree in the fall and winter.

The fungus slowly spreads from the roots of an affected tree to the roots of the surrounding healthy trees, often killing a tree in each direction in from one to four years. W. T. Horne,[47] who has investigated this disease in California, states that trees not girdled by the fungus may be kept alive for many years by digging around the tree, removing all diseased roots and decayed patches of bark and disinfecting the cuts.

In the handling of areas or spots in an orchard where Citrus trees are affected or killed out, it is necessary not only to check the outward advance of the fungus so that new trees will not become infected, but to treat the area already affected before replanting.[48] To prevent

[47] Horne, W. T., Calif. State Comm. of Hort. Mo. Bull. 3:275–282, 1914; 4:179, 1915.

[48] Barrett, J. T., Calif. Citrograph, 3:77–78, 1918.

new trees from becoming infected, Professor Horne suggests digging ditches so as to inclose the affected areas. For killing out the fungus in the soil of the affected area before replanting, 1½ ounces of carbon bisulphid poured into holes 1½ feet apart each way and 1½ feet deep has been used usually with good results.

BOTRYTIS GUMMOSIS

SYMPTOMS AND OCCURRENCE

Botrytis gummosis[49] differs from brown-rot (Pythiacystis) gummosis, in that it causes softening of the invaded bark in the early stages and shows a gray color on the surface in damp, cool weather, caused by the conidiophores and spores of the fungus (fig. 8). In the later stages the outer layer of bark is killed and becomes dry and hard much in advance of the inner layer, while there is a greater tendency than in brown-rot gummosis for the tree to renew the bark underneath the dead, hard layer, and there is usually also a less copious flow of gum. Unlike brown-rot gummosis, Botrytis gummosis is confined in California almost exclusively to lemon trees growing in the coastal regions, and usually occurs on trees that are more than 10 years of age. This disease should not be confused with "shell bark," a desquamated bark condition in which the outer bark of lemon trees dies, cracks and breaks away in longitudinal strips, a condition which is somewhat similar to that frequently brought about in the later stages of Botrytis gummosis. These two diseases are often associated on the same trees. The conditions favorable to the one are also apt to encourage the other. Neither disease should be confused with psorosis (scaly bark) of sweet-orange trees.

Unlike *Pythiacystis citrophthora*, the causative fungus, *Botrytis cinerea*, is not able to gain entrance except through some wound or defect in the bark, and is not able to progress so rapidly in killing the bark through to the wood. A large area is involved, in which only certain outer layers of bark tissue are killed, leaving the cambium alive and capable of renewal. This gummosis produces an outer gummous zone beyond the invaded area, but this is usually less extensive and less rapidly formed than with Pythiacystis gummosis. Other conditions being equal, there is usually somewhat less gum formation in Botrytis gummosis than in Pythiacystis gummosis.

[49] Fawcett, H. S., "Two fungi as causal agents in gummosis of lemon trees in California," *in* Calif. Comm. Hort. Mo. Bull. 2:601–617, 1913, and Phytopathology, 4:54, 1914.

My attention was first called to this type of gummosis early in February, 1912. After a period of moist, cool, weather, patches of bark 6 to 12 inches long and half as wide presented the gray furry appearance characteristic of the fruiting bodies of *Botrytis cinerea* (fig. 8). In a later survey of the Citrus districts of California, *Botrytis cinerea* was always found associated with this type of gummosis and was isolated from a large number of diseased trees.

INVESTIGATIONS AS TO NATURE AND CAUSE

The investigations establishing the relation of the fungus, *Botrytis cinerea*, to this disease were conducted in much the same way as those in connection with brown-rot gummosis.

(1) Inoculation with diseased tissue showed that the disease could be transmitted to sound bark of healthy trees.

(2) Cultures from the diseased lesions showed the presence of a fungus, *Botrytis cinerea*, previously known as the Botrytis rot fungus of the packing houses.

(3) By inoculation experiments with pure cultures of this fungus the characteristic symptoms were induced on healthy trees (fig. 9).

(4) Inoculation with Botrytis fungus isolated from lemon fruits also produced the same results.

(5) The Botrytis fungus was again isolated from the artificially induced lesions and was found capable of inducing rot in lemon fruits irrespective of whether it had been found originally in diseased bark or in rotting fruit. Some of the details of this work are published elsewhere.[50]

The fungus was isolated from the softened invaded area of a large number of these lesions. Attempts to isolate the fungus from the outer gummous zone, however, failed, just as they did in Pythiacystis gummosis. Only rarely was Botrytis isolated from the area where the outer bark was dead and hard. Cultures showed that after Botrytis infection this outer dead cortical layer is rapidly occupied under such conditions as prevail at Santa Paula by species of Alternaria, Cladosporium, Penicillium, Colletotrichum, Fusarium, and other fungi and bacteria.

[50] Gummosis of Citrus. Jour. Agri. Res. 24:191–236, 1923.

Fig. 8.—Gray masses of spores of *Botrytis cinerea* on the surface of bark of a Botrytis gummosis lesion.

FACTORS FAVORING THE DISEASE

Many contributing conditions tend to favor the occurrence and the severity of this disease. Some of these are similar to those which favor Pythiacystis gummosis.

Injuries of various kinds to the bark, not only near the soil, but anywhere on the trunk or large branches, may lead the way to infection and development of Botrytis gummosis when the conditions of moisture and temperature are also favorable. This disease is frequently severe on living tissue of trees that have been injured by frost. The fungus may first become established in such trees in a small portion of dead or dying tissue and then advance rapidly into tissue which appears to be sound.

A desquamated condition of bark, known as decorticosis, is frequently associated with Botrytis gummosis. It furnishes dead outer bark tissue from which the fungus may advance. Decorticosis is similar in appearance to the effect which often follows inoculation with *Botrytis cinerea* on sound tree trunks and with which it is often confused.

The previous use of neat's foot oil in the treatment of gummosis encouraged the growth of the Botrytis fungus. The trunks of lemon trees treated by scoring the bark and painting with neat's foot oil were observed in February and March of 1912 to be fairly well covered with a gray coating consisting of the sporophores and spores of Botrytis. The bark on these trees was found to be in various stages of soft decay with the exudation of large masses of gum. Experiments also showed that this fungus develops better on lemon bark treated with neat's foot oil either before or after infection by the organism than on bark free from this oil. In recent years the application of neat's foot oil to Citrus trees has been largely given up, and the more severe stages of this disease, such as were previously seen, have not been observed lately.

METHODS OF CONTROL

The control methods used for Botrytis gummosis as in the case of Pythiacystis gummosis are of two kinds, preventive and curative; both of which are similar in principle to those discussed in connection with the former disease. A few modifications, however, based on the differences between the two diseases should be pointed out.

Prevention.—Since *Botrytis cinerea* appears to be dependent upon abrasions or other injuries for its entrance into lemon bark, especial

care is necessary, particularly in moist weather, to avoid injuries in cultivation, picking and other orchard operations. The danger from such injuries may be lessened by painting the tree trunks with Bordeaux paste or other fungicides or spraying them thoroughly with Bordeaux mixture. The precaution previously mentioned of pulling away soil that is too high against the trunk and of keeping water as much as possible away from the trunk, are also applicable in the case of Botrytis gummosis.

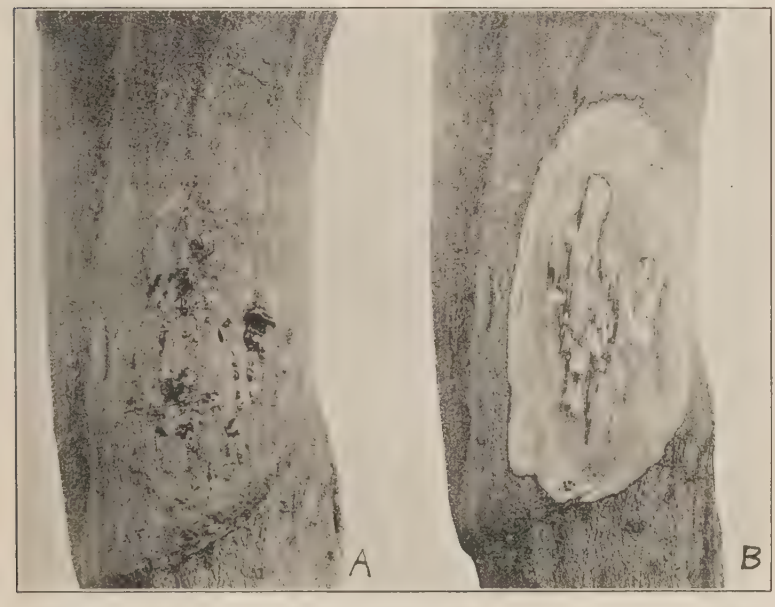

Fig. 9.—(*a*) Gum exudation on a lemon trunk as the result of inoculation with the Botrytis fungus.

(*b*) Bark over and around the diseased lesion scraped, to show the extent of the dead soft bark.

Treatment.—The principle governing the treatment of this type of gum disease is the same as that for Pythiacystis gummosis, namely, the elimination of the invaded tissue and the prevention of further progress of the disease. As the result of many different experiments in which growers took a prominent part, a method consisting largely of scraping off the outermost layers of bark was found which proved to be best adapted for treatment of this disease (fig. 10). The portion where the bark is totally killed is cut away, but beyond this where usually only the outer layers of bark are dead, these outer layers only

are scraped off, leaving intact the live inner layer next to the cambium. To prevent further invasion of the outer bark it is usually found necessary to scrape the sound bark several inches beyond the margin of the affected region. A sharp curved tool, described under

Fig. 10.—Treatment of Botrytis gummosis.

(*a*) Lesion being scraped.

(*b*) Painting scraped area with Bordeaux paste.

"psorosis," which can be easily controlled in scraping, is in general use for this purpose (fig. 15). This modification of the method used for Pythiacystis gummosis is advisable because of the different nature of the disease, in order to preserve as much as possible of the inner live bark. Where both types of gummosis are present on the same

trees, as is frequently the case, this method is still applicable to the combined lesions produced. The cut or scraped portions are then painted with a fungicide (fig. 10*b*). Bordeaux paste, and some of the coal tar products, such as Avenarius Carbolineum, and Arrow Carbolineum, which contain only the heavier oils, have given good results.

The following is a typical example of the many experiments in treatment of this disease:

On October 8, 1912, at Santa Paula, a lesion on the trunk of an 18-year-old lemon tree was treated by cutting away the bark entirely in a few small places where it was killed to the wood, but scraping away only the dead outer layers elsewhere and leaving the cambium still attached (fig. 10*a*). The scraping was done with a sharp curved instrument made on the principle of a box scraper, and the scraped portion was then painted with Bordeaux paste (fig. 10*b*).

On May 10, 1913, new bark was building up over the scraped portion, but the disease had spread slightly on the margins where scraping had not been continued out far enough. It was then scraped again.

On May 17, 1914, new bark was seen to have formed over the entire scraped portion and the disease appeared to be completely checked.

SCLEROTINIA GUMMOSIS DUE TO SCLEROTINIA LIBERTIANA

This disease, usually of minor importance, occasionally has been found associated with rapid dying of bark on the roots and trunks of Citrus trees growing in damp, cool locations especially after periods of severe frost. The bark is at first soft just as in the case of attack by *Botrytis cinerea*. Though this fungus usually advances more rapidly than Botrytis, it is soon checked, and callus begins to form as soon as gum accumulates. Later, as the bark dries, it is left in shreds (fig. 11) and large black sclerotia are found within and under this bark. Its effect on twigs has been described by C. O. Smith,[51] who refers to the gumming usually accompanying its attack. It appears to infect the young growth, usually at the blossoming period, and frequently extends back into larger branches.

When the fungus is found on the trunk or roots, observations have indicated that previous injury of the bark was usually necessary

[51] Smith, C. O., Cottony rot of lemons in California. Calif. Agr. Exp. Sta. Bull. 265:237–258, 1916.

for its entrance. It has frequently been found on young trees after frost injuries, apparently advancing from frost injured tissue into tissue not killed by frost. It has been observed on a lemon tree 20

Fig. 11.—Root of lemon tree showing shredded appearance of the bark and the black sclerotia as the result of the attack of *Sclerotinia libertiani*. Arrows point to sclerotia.

years old where all the roots had been infected, probably at wounds made in digging about them and placing vetch straw near the crown in damp cool weather. An old seedling orange tree also was observed with the bark on one side of the trunk killed by the fungus, which

had apparently gained entrance through a small sunburned area and thence advanced into the live bark for some distance.

This fungus has also been shown by inoculation experiments to be capable of advancing rapidly into lemon bark, inducing copious gum formation for a short time only. Observation shows that the halting of the invasion of the fungus is usually coincident with the exudation of considerable quantities of gum. The prevention and treatment of this disease is the same as that for Botrytis gummosis. (See directions under Botrytis gummosis, page 35.)

PSOROSIS (SCALY BARK) OF ORANGE TREES

Although psorosis is generally classed as a gum disease, gum exudes only at certain seasons, or during certain phases of development of the disease, and then the gum is usually not so conspicuous a feature as it is with brown-rot gummosis.

This disease was briefly described by W. T. Swingle and H. J. Webber in 1896 in Florida and given the name of psorosis.

It is now known in California as "scaly bark," but must not be confused with another disease known in Florida as scaly bark (nailhead rust). This is distinct from psorosis and does not occur in California.

The slowness of the development of the disease, and its inconspicuous appearance and lack of effect upon the foliage in the earlier stages, frequently prevent it from being noticed until it is far advanced.

SYMPTOMS

The most conspicuous feature of the scaly-bark disease is the appearance on the trunk or large limbs of irregular scales of bark $\frac{1}{4}$ to 1 inch in diameter, standing out as if pushed off from the surface (fig. 13). It usually begins with a very small area in which only a thin outer layer of bark dies, hardens, and is raised from the surface (fig. 12), leaving a layer of bark underneath still alive. This first area slowly enlarges from year to year until finally it encircles the trunk or limb (fig. 14*a*). Often a number of small areas begin at the same time and thus cover the surface more rapidly. Later the deeper layers of bark and even the wood may be affected. Gum may exude as the disease advances, but gum is not a necessary accompaniment of the disease and its presence and amount depend on growth conditions, season of the year, etc.

INVESTIGATIONS AS TO CAUSE AND MANNER OF DEVELOPMENT

An investigation into the cause and manner of development and the control of this disease, has been carried on for years. Many difficulties which were not encountered in the work with brown-rot gummosis have arisen in the investigation of the cause of psorosis. One of these has been the extreme slowness with which the disease develops in its incipient stages.

Fig. 12.—Small lesions of psorosis (scaly bark); one showing bark breaking away in scales; others above showing a roughness of bark. Slightly magnified.

In certain cases it has been possible to transmit the disease to sound trees by inoculations with bits of tissue from diseased lesions, but many of the attempts have failed. In one of the successful cases two years elapsed after the diseased tissue was placed in a wound in sound bark, before any sign of the disease was noted. This suggests that an organism of some kind which is able to advance very slowly

may be the immediate cause of the disease. Experiments planned to determine whether this hypothesis is correct have been under way for some time, but because of the slowness of development of psorosis from the early stages there has not been time for proof of this conjecture to be established.

Fig. 13.—About the second stage of psorosis (scaly bark) on orange trees, showing formation of scales of bark, giving the surface a roughened scaly appearance.

As examples of the slowness with which the disease often develops, the following cases may be mentioned. At the Experiment Station two incipient lesions not yet gumming, and each about 1 inch in diameter were outlined on a Valencia orange tree 12 years old. These lesions had progressed only $\frac{1}{4}$ inch beyond the original mark in 2½ years. A slightly larger area on another tree, which was 1½ inches

in diameter when first observed became only 4 inches in diameter in $3\frac{1}{2}$ years. These areas were so small and inconspicuous when outlined that they would not have been noted at all at that stage by most growers.

After the lesions become larger, however, they develop somewhat more rapidly. The following example represents a rather rapidly developing lesion. An area on a trunk of a 12-year-old Valencia tree was 3·7 inches when marked. Six months later it was 8·12 inches; after 9 months, 10·15 inches; after 2 years, 12·16 inches (with much gumming), and after $3\frac{1}{2}$ years 14·17 inches. While this increase from 3·7 inches to 14·17 inches seems considerable in itself, it represents an average of only about $1\frac{1}{2}$ inches of advance per year in any one direction. The lesion was probably 3 to 4 years old when first measured. Scaly bark thus differs from any other gum diseases, whose whole course of development can be followed out in 1 or 2 years.

The visible advance of the disease depends greatly upon the season of the year. In the majority of cases it seems to be most active during the growing season and especially in summer and early fall, and to be quiescent during the winter and early spring. This summer increase of activity is due in part to the breaking away of scales of bark, probably brought about not only by drying of the outer bark that has previously died, but also by the increase in growth of the inner live bark beneath. Gum formation and exudation also take place at this season, giving further indication of activity. Most of the advance for the year, however, appears to be finished when the gum formation is at its maximum. The gum is the result and not the cause of the death of the outer bark. The gum probably tends to hinder more than to aid the advance of the disease at this time.

EXPERIMENTS IN TREATMENT

Although the investigation as to the cause and manner of development of the disease received first attention, a number of experiments in control have also been carried on. Various methods of cutting, scraping and slitting the bark have been compared with no cutting or scraping. Comparisons have also been made of the application of a considerable number of substances as fungicides or coverings.

Without going into detail, it may be said that a method of scraping the outer bark to depths varying according to circumstances, to be described later, has been found more effective than any other method (fig. 14). Scraping has been found to be much more import-

ant than the use of any kind of fungicide or disinfectant. Slitting has proven of little or no value in these experiments. These experiments have also shown the advisability of scraping not only the area visibly affected, but also beyond the area to a distance of from 6 to 8

Fig. 14.—A. Psorosis second stage on Valencia orange trunk. Area had previously been whitewashed but not scraped. B. Same tree after scraping outer layers of bark for about six inches beyond the diseased area. Scraping a little deeper at the advancing edge than here shown is advisable for ideal treatment.

inches to head off the advance of the disease in bark not yet visibly affected. The spread of a lesion in its early stages appears to take place within the outermost layers of bark. This accounts for the beneficial results of light scraping beyond the visible edge of the lesions.

A large number of disinfectants and coverings were tested with and without scraping or other method of cutting the bark. In each case similar areas on the same or different trees were left without the application of the disinfectant for comparison. Almost without exception the diseased trees on which the bark was carefully scraped showed the best recovery. The disinfectant applied seemed to have little effect. Lesions of the same kind not scraped continued to develop in size at the same rate, whether painted or unpainted with the various disinfectants.[52]

The results of experiments obtained so far indicate that the particular fungicide applied is of less importance than the manner of scraping or treating the bark.

SUGGESTIONS FOR TREATMENT

The stage of the disease largely determines how the tree should be handled. Each tree affected presents an individual problem. The general suggestions made here apply to typical conditions and may need modification for particular cases.

First Stage.—At the very beginning (fig. 12) only an outer layer of bark appears to be injured or changed, an inner layer next to the cambium still being alive and active and free from discoloration except that it frequently presents a slight greenish appearance. Later a yellowish discoloration may appear, due to the development of gum within the tissue. The trunk and large limbs of all trees should be inspected carefully to detect the disease at its very beginning. When the beginning areas are small and do not cover more than ¼ of the circumference, the affected bark may be scraped rather deeply and the surrounding apparently unaffected bark scraped less deeply for 4 to 6 inches in all directions beyond the margin of the affected areas.

Second Stage.—When the disease has progressed further, so as to cover more than about ⅓ of the circumference of the entire bark on the trunk but has not yet seriously injured the wood, it may for convenience be considered to be in the second stage. At this stage the affected portion often presents a roughened surface (figs. 13 and 14).

Fresh scaling of the bark on the advancing edges continues and exudation of gum takes place at certain seasons of the year. In such cases the cure is more uncertain, but the disease may be checked

[52] Rounds, M. B., Ann. Rept. Calif. Citrus Institute, 1921–22, p. 54–60.

and sometimes cured by a light to medium scraping. Particular attention should be given to the advancing edges. The affected surface may then be treated with one of the fungicides mentioned later. Six months or a year later, these should be treated again, scraping only where the disease is still active. The progress of the disease is so slow that usually one cannot discern within less than six months to a year or more, whether it has progressed or not.

Third Stage.—Where the disease has been present for a number of years (5 to 10 or more) or until a greater part of the bark of the trunk is affected and the wood underneath is killed and beginning to decay, there is little hope for a permanent recovery. A tree of this kind, however, sometimes remains surprisingly productive for a number of years, so that it becomes a question whether to replace it at once or to treat it superficially with the idea of preventing possible spread to other trees, and of taking it out later. If only a part of the branches show the disease in the second and third stages, these may be cut out entirely and the remaining part of the tree frequently inspected for further outbreaks. If the wood is just beginning to be discolored and killed, this should be chisled out and benzene-asphalt paint, white lead or other good wood protecting covering applied to the exposed surfaces. A severe cutting back of a badly affected tree may be helpful. If the trunk is too badly decayed and the entire tree appears stunted and unproductive, the tree should be dug out.

Season of the Year.—Where there is much frost hazard, bark scraped too late in the fall or during the winter months is likely to be killed by low temperatures. Experiments at Riverside indicate that bark treated in the late spring and summer months recovers most rapidly.

Fungicides.—As was previously stated, the kind of fungicide employed appeared to be of minor importance in certain of our experiments. Some kind should be applied, however, to the scraped areas, as a matter of precaution. Except for the slight danger to the foliage when followed by fumigation there is nothing better than Bordeaux paste. Other substances of good fungicidal value are some of the high-boiling coal tar products such as Arrow Carbolineum and Avenarius Carbolineum.

Other safe fungicides of known composition are: mercuric chloride 1 gram to 1000 cc of 25 per cent denatured alcohol (⅛ ounce to one gallon) or mercuric cyanide of the same strength; emulsified cresol (liquor cresolis compositus USP) 10 per cent in water; or potassium permanganate crystals 1 per cent in water (one ounce in 3 quarts of water). The mercuric chloride and mercuric cyanide

may be obtained as tablets or in crystalline form, the potassium permanganate and copper sulphate in crystalline form, the liquor cresolis compositus and carbolineums in liquid form. These are sold by drug stores, drug companies and spray dealers.

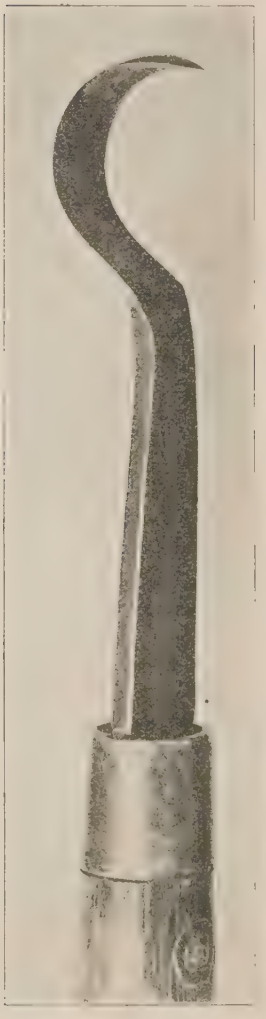

Fig. 15.—Tool for scraping the bark or for gouging out small diseased areas caused by psorosis or other bark diseases.

Before applying to the bark carbolineum or any other product the exact composition or effect of which is unknown, it should be tested on some leaves and twigs several days before it is to be used on the bark. If in two or three days it does not seriously injure the nature leaves or twigs it will probably be safe to apply to the bark. If, however, the leaves are severely burned, the product is usually not safe to use on the bark.

For Bordeaux paste, dissolve 1 pound of bluestone (copper sulfate) in 3 quarts of water in a wooden, earthen or glass vessel and slake 2 pounds of lime in 3 quarts of water. The bluestone is most easily dissolved by suspending it in a sack at the top of the water overnight. If the bluestone is pulverized and suspended in warm water it dissolves rapidly. Good lime that is not air-slacked should be used. If covered to avoid evaporation the dissolved ingredients will keep indefinitely in separate vessels. Where the paste is being used over a number of days or weeks, just enough of the wet slaked lime and the bluestone solution should be mixed to last for one or two days. It may be applied with large whitewash brushes. Commercial Bordeaux pastes and powders brought to equivalent strength may also be used. Most of these will require the addition of some lime paste.

Tools.—A number of different kinds of scrapers are in use for scraping the bark. Several types devised by Mr. Culbertson of the Limoneira Company for use in the treatment of Botrytis gummosis are shown

in figure 10. A modification of one of these, first made under the direction of Dr. J. T. Barrett of the Citrus Experiment Station, is now in common use. It may be made of spring steel and consists of a curved blade sharpened on both edges and at the end and set in a wooden handle. The handle is 7½ inches long and 1¼ inches in diameter and the steel part, including the curved blade, is 5½ inches long (fig. 15). These can be made by a local blacksmith or obtained through the farm advisor.

DECORTICOSIS OR SHELL BARK OF LEMON TREES

Decorticosis (shell bark) is a disease affecting the outer layers of the bark of lemon trees principally that of the trunks. In some instances, the disease spreads up on to the basal portion of the larger limbs, but in general it is confined to the bark of the trunk. It is not known to affect anything except the lemon bark. The general aspect of decorticosis recalls the loosening bark of shell bark hickory tree of the eastern states. This resemblance, spoken of by Fawcett[53] in describing the disease, led Coit and Blanchard[54] to employ the term "shell bark."

Shell bark is frequently confused with psorosis of orange trees, a very different disease which never spreads to the lemon bark.

Distribution and History.—It is not known how widely this disease occurs in various countries which grow lemons. It does not appear to have attracted any attention in California until recently. It was already fairly common in many orchards, however, in 1912, when my investigation of Citrus diseases in this state began, but no definite published mention of the disease had been seen at that time. Lemon tree trunks showing similar symptoms were seen in Florida and Cuba in 1914[55] and in Sicily in 1923.[55] It is probable that it has been in existence for a long time and may be widely distributed. A species of fungus, *Phomopsis californica*, has been shown to play a part in the development of the disease.[56]

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[53] Fawcett, H. S., Citrus diseases of Florida and Cuba compared with those of California. Calif. Agri. Exp. Sta. Bull. 262:149–210, 1915.

[54] Coit, J. E., and Blanchard, V. F. Calif. Citrog. 7:259–292, 1922.

[55] Fawcett, H. S., Observations on bark diseases of Citrus trees in Sicily. Phyto. 15:41–42, 1925.

[56] Fawcett, H. S. A new Phomopsis of Citrus in California. Phyto. 12:419–424, 1922; Shell bark of lemon trees, Calif. Citrograph, 9:330, 1924.

Symptoms.—Shell bark is found only on lemon trees or on trees having lemon trunks. The outer bark dies, shrinks and cracks and (in advanced cases, fig. 16) tends to loosen in vertical strips. The drying and cracking of the outer bark frequently starts at the bud union near the soil and gradually works upward till the entire trunk is involved (fig. 16). In pure shell bark that is not accompanied by gum diseases, the inner bark and cambium remain alive and tend to build up new layers to replace the outer destroyed layer. Young bark appears to be immune to the disease, it being found only in connection with bark of a considerable age.

Fig. 16.—Showing the cracking and scaling due to decorticosis (shell bark) on old lemon tree trunks in California. Note the freedom from cracking on the orange stock below the bud union.

As a rule the disease does not appear until a lemon tree is from 15 to 20 years of age. With some varieties, as the Lisbon, the age at which the disease starts may be 20 to 30 years. Some susceptible strains of Eureka, however, may begin to be affected when only 10 to 12 years old.

The general effect on the foliage and appearance of the tree may be quite marked when shell bark is advancing rapidly in the bark tissues. The leaves gradually turn a bronze color, some of them fall prematurely, leaving a rather sparse foliage or bare twigs, the tips of which may die back for a short distance. In less severe cases there may be only an indefinite "off color" and lack of vigor without any characteristic symptoms in the top of the tree.

After the entire outer bark of the trunk has become involved and begins to crack and loosen in strips and the inner bark begins to build up again, the foliage may wholly or partially recover its former green vigorous appearance. In certain Eureka lemon orchards

where observations have been made for about 12 years, the shell bark has reappeared in a more or less active state in cycles of about four or five years.

The general effect on the foliage and appearance of the tree may not show any striking damage from its presence. The bark underneath the affected areas has time to recover almost as rapidly as the disease advances, so that no striking effect is noted.

Contributing Conditions.—Shell bark is apparently more prevalent in the moister coastal and foothill sections than in the dryer interior valleys. Degree of moisture in the atmosphere is probably one contributing condition. The disease is also likely to start in slight injuries or growth cracks in the outer bark tissues. The most common place for the diseased areas to start is the bud union probably at injuries or growth cracks. If the moist soil is allowed to remain against the bark at or above the bud union a favorable condition exists for the start and development of the disease.

Susceptibility of varieties and strains is also a contributing condition. Observations regarding this disease indicate that Eureka lemons are more susceptible than Lisbon and that certain strains within the Eurekas are more resistant than other strains of the same variety. In general Eureka trees are 15 to 20 years old before shell bark begins to affect the bark to any extent. Lisbon lemon trees are usually older than this before they begin to show its effects and even then its progress on Lisbon is usually very slow.

Examples of extremely susceptible strains of Eurekas have been noted on which shell bark began at the age of 8 to 10 years. When the parent trees from which these susceptible ones had been budded were examined, it was found that the trunks and also the bases of the oldest limbs were covered with shell bark. There were indications on the trunks that a new bark had formed, two or three different times, by a repetition of the shelling off process. Trees from the same source which had been sent to another locality many miles distant also showed this tendency to contract shell bark at an early age.

A second example is that found in an orchard where 12 trees, 18 years of age, at the end of a single row, had shell bark, while no trees on adjoining rows had contracted the disease. Further observation showed that these 12 trees were of one type and probably came from the same bud stick. It was later learned that the trees had been budded with lemons after they had been planted and that the budding had probably proceeded in the direction indicated by the row of affected trees.

Control.—The control methods for this disease are still in an experimental stage in California. Certain suggestions as to prevention and treatment however arise from the knowledge of the nature of the disease and observations regarding the contributing factors.

Prevention.—As in many other bark diseases the avoidance of injuries to the bark is important. It is expected also that certain disinfectants or fungicides will be a help in preventing the development of the organism. The selection of resistant varieties or strains is also a possible means of preventing the disease in new plantings.

Observations indicate the importance of selecting buds from trees that are free from shell bark after they have attained a considerable age. Such buds will probably be more likely to give trees that are resistant to shell bark than trees from bud-wood taken from a tree, under the same conditions, that has already contracted the disease.

Treatment.—Whether it is feasible to treat trees for shell bark depends largely on the age of the trees and their degree of susceptibility.

When the disease is just starting on a tree and appears to be progressing rapidly, results so far secured seems to indicate that it is a good practice to scrape not only the diseased area (much in the same manner as is done in the treatment of psorosis of oranges), but also to scrape the entire trunk, being careful to remove only a thin outer layer so as to disturb as little as possible the inner bark and cambium. The trunks can be treated with some good fungicide such as is used in psorosis treatment (page 44). It seems advisable also to thin out the branches in the top at the same time that this treatment is given.

When shell bark has already involved the entire trunk, or a greater portion of it, and a new bark has been formed underneath and the old is shelling off, it is uncertain whether a severe scraping is then advisable, especially on trees where the disease is progressing slowly and is not complicated with gum diseases such as Botrytis gummosis or other forms of gum disease. These gum diseases often follow or accompany the shell bark and should, of course, be treated.

A thinning of the branches appears to be beneficial in trees that have deteriorated on account of the presence of shell bark.

DIPLODIA GUMMOSIS[57]

In a former publication [58] it was stated that this form of gumming had not been seen in California, but was common in southern Florida and Cuba. Since then a Diplodia fungus similar to that of Florida has been found frequently in California, especially in San Diego County, associated with a gumming of large branches. A gummosis

Fig. 17.—Gumming (at the point of the arrow) on lemon bark, due to *Diplodia* sp. following a severe frost injury.

[57] Fawcett, H. S., *Diplodia natalensis* as a gum-inducing and fruit-rotting fungus. Report of plant pathologist, Fla. Agr. Exp. Sta. Ann. Report, 1911, 61–67,1912.

Gumming, Report of the former Plant Pathologist, Fla. Agr. Exp. Sta. Ann. Report, 1912, 77–92, 1913.

[58] Fawcett, H. S., Citrus diseases of Florida and Cuba compared with those of California. Univ. of Calif. Agr. Exp. Sta. Bull. 262:210, 1915.

due to a Diplodia has been found recently in the Philippines also.[59] This fungus appears to be especially active in California in connection with the so-called "heart rot" induced by severe freezes. In 1913 this fungus was found advancing into the yet unkilled wood of large branches which had been cut off after the freeze with the result of frequent gum formation. The fungus advanced much more rapidly in branches whose cut ends were sealed with grafting wax than in those not so sealed. The Diplodia attack resulted indirectly in the death of areas of bark, but the fungus advanced much more rapidly in the woody tissue (fig. 17).

Control.—The heart rot due to Diplodia following a severe freeze is difficult to control. A non air-tight disinfectant, such as Bordeaux paste, mercuric cyanide (1 part in 1000 parts of 25 per cent denatured alcohol) should be used to disinfect the tools and cut surfaces. This treatment may be followed by a sealed covering sometime later when the wound has thoroughly dried out. If only one application is to be used, a thin substance like the higher boiling coal-tar products, such as Avenarius carbolineum or Arrow carbolineum, may be used. All parts of the tree cut back should be thoroughly whitewashed to prevent sunburning.

DOTHIORELLA GUMMOSIS

A form of gummosis similar to Diplodia gummosis on lemon trees in California has been shown by recent experiments to be due to a fungus similar to *Dothiorella ribes* Gross and Dug. (Botryosphaeria ribes).* Gum in considerable quantities oozes from a fusoid gum pocket on the trunk or large limbs. This form has been referred to by some growers as "pocket gum." The dead bark areas vary in size but are usually not extensive. The inner bark tissue is often disintegrated and dissolved. This leaves elongated cavities and grooves in the inner bark next to the cambium region. The inner bark is chocolate brown. The wood below the pocket is often discolored inward for a short distance beyond the cambium. There is also a gummous zone near the cambium like that described in Botrytis and Pythiacystis gummosis. These lesions have a tendency to become self limited before becoming extensive and to fill up with new bark tissue at certain seasons and later to become active again. The same fungus that causes Dothiorella gummosis is also responsible for Dothiorella rot of fruit. The contributing factors and control would probably be the same as those given for Diplodia gummosis.

* The author is indebted to Dr. C. L. Shear for identification of this fungus.

[59] Reinking, O. A., Philippine Agriculturist, 9:123–127, 1921.

CITRUS BLAST

Citrus blast is an effect of a bacterium, *Pseudomonas citriputeale*, on leaves and twigs.[60] The same organism also produces a spot on fruit known as black pit.[61] For detailed discussion of recent investigations on this disease see account by Fawcett, Horne and Camp.[62]

Symptoms.—The most striking characteristic of the blast manifestation is an area shading from brown to black, which usually starts in a tear or break of the wing of the petiole and extends rapidly into the base of the leaf blade and to the twig surrounding the base of the petiole. During cool, damp weather these areas enlarge rapidly, but when the dry and warmer weather comes the progress of the lesions is checked. The following features are to be noted: there is a definite line between the dead and live tissue; new callus tissue forms under the affected areas; the surface of the affected bark becomes dry, the initial black color changes to a reddish brown and scabs are formed. If the disease progresses very rapidly the leaves wither and die while still attached to the tree (fig. 18); but if the progress is slow or if it occurs at a somewhat warmer temperature, an

Fig. 18.—Showing small lesions surrounding attached petioles. These have attained their maximum development at the end of the active period. Near the center is a typical example of the many dead dry leaves which frequently remain firmly attached through the subsequent summer and fall.

[60] Lee, H. Atherton. A new bacterial disease of Citrus. Jour. Agri. Res. 3:108, 1917.

[61] Smith, C. O. Black pit of lemon. Phyto. 3:277–283, 1913.

[62] Fawcett, Horne and Camp. Citrus blast and black pit. Univ. of Calif. Agri. Exp. Sta. Technical paper, 5:1–24, 1923.

abscission layer is formed and the leaves are shed. In the latter case, it seldom progresses further than the petiole of the leaf, and few lesions will be formed on the branches. In very severe cases the disease may progress so rapidly as to girdle the twigs and cause many of them to wither and die; but more frequently the lesions are checked before girdling takes place. Microscopic examinations have shown that the bacteria are most abundant in the layers not far from the cambium. They appear to attack the parenchyma tissue principally, and do not kill the woody tissue except in extreme cases. When the temperature is medium or high after the disease starts some gum formation may take place. As black pit the disease manifests itself on the fruit, especially in the case of lemons, as sunken black spots. As these develop they change from a light brown to dark brown, and then to black. The inner white part of the peel is also affected. There is a collapse of the tissue, which finally becomes light brown tinging to reddish brown in color.

Control.—Spraying experiments have been carried on for five consecutive years, and the results each year have indicated that Bordeaux mixture, if applied as early as the first of November, will prevent a considerable part of the injury from this disease. It is of little advantage if applied some weeks later. Since seasons favorable to Citrus blast however occur only about once in three years it appears doubtful whether the expense of a yearly spraying is justified by the returns.

It is believed that the same expense in good cultural care will bring greater returns. Observations have indicated that orchards which are well taken care of and given adequate fertilization, irrigation, and other cultural attention, are usually little affected as compared with orchards where it has been impossible to give all the care that is necessary. Blast appears to be no more serious than a light or moderate pruning or defoliation by dry winds. Orchards protected from the driving winds that often come with the rains are also apt to have only a slight amount of the blast. Windbreaks or other protection from the wind should be provided, especially for new plantings. Such protection together with proper cultural care appears to prevent most of the loss from Citrus blast.

These suggestions are of little importance for conditions in southern California, since the disease is a minor one there, usually manifesting itself only in black pit of the fruit which is seldom of sufficient importance to demand a remedy. With regard to protection against injuries the same principles apply to all sections.

TWIG GUMMING

A gumming and dying of a few scattered twigs, especially on navel orange trees, in the late summer or fall, is usually of minor importance. It occurs in both California and Arizona. The cause is unknown. It is characterized by sudden wilting of leaves and dying back of twigs or small branches to a distance of 12 to 24 inches from their tips. At the base of the dead portion, the bark splits and gum oozes out in considerable quantities. It appears to occur most often after periods of hot dry weather and has been known in California for many years as a minor trouble. It is quite distinct from Citrus blast though sometimes confused with this disease.

A somewhat similar gumming, associated with the dying back of twigs and branches but without the characteristic splitting of the bark, has frequently been noted in large nursery trees. Although certain organisms have been found in the lesions none of them have reproduced the disease on inoculation. These forms of twig gumming differ from twig blight caused by the cottony rot fungus, *Sclerotinia libertiana*, in the absence of a whitening or shredding of the bark and of the black sclerotia frequently formed in the bark attacked by that fungus.

EXANTHEMA

Nature and Symptoms.—Exanthema, or die-back as it is commonly called in Florida, is often classed as a gum disease although gum formation is not always a conspicuous feature. The clear gum seen in connection with exanthema exudes only from gum pockets on the twigs, or is formed internally near the center of the fruit at the angles of the segments (fig. 19.) Dark excrescences and multiple buds on the branches, dying back of terminal branches, compact shortened growth and dark irregular reddish brown patches on the surface of the fruit are other symptoms.

The disease has been considered to be the result of a nutritional disturbance, but the actual cause is unknown. Localized areas in California orchards showing exanthema have frequently been noted where sheep corrals or cattle barns had been located in previous years. It has also been found in other instances to correspond to spots where the top soil had been graded off in leveling the orchard before planting. Although the use of large amounts of organic nitrogenous fertilizers,

such as dried blood and cottonseed meal have been considered to be contributing factors in inducing exanthema on some soils in Florida, these fertilizers have not been observed as a rule to encourage the disease under conditions in California.

Fig. 19.—Cross-section of a green orange from a tree affected with exanthema. The dark areas between the septa next to the core indicate the presence of clear gum that has taken the place of the normal tissue.

CONTROL

In many cases in California where exanthema has been troublesome in young trees in localized areas, the trees have outgrown the trouble without any special treatment. In cases where the contributing conditions are such as may be economically removed by the grower the remedy is, of course, obvious.

Exanthema is of such minor importance in most sections of California that no study has yet been made of special methods of control. The methods used in Florida cannot be recommended for California without trial as the disease is here manifested under such widely different conditions.

OTHER MINOR FORMS OF GUMMING

In addition to the gum diseases already discussed there frequently occur minor forms of gumming, some of which have been shown to be induced by microörganisms while other forms are brought about by insect injuries, chemical stimuli, or in certain cases by physical effects of the environment.

Most of these forms of gumming cannot be classed as definite diseases and are of minor importance commercially as compared with the preceding diseases.

PENICILLIUM ROSEUM

Gumming due to Penicillium roseum. This fungus, which forms small pink tufts of hyphae and spores on the surface of lemon bark, is capable of inducing a small amount of gum exudation and death of small areas of bark, as has been shown by inoculations with pure cultures. It has been found as a secondary fungus associated with Botrytis gummosis and shell bark on lemon trunks, mostly in the moister coastal sections of California. It is also associated with a minor decay of lemon fruits.

FUSARIUM

Many species of this genus of fungus produce pinkish to red pustules or masses of spores within the surface layer of dead bark of lemon trees. In general appearance and color these red masses look to the unaided eye much like those of *Penicillium roseum*. This fungus also has been shown to be capable of inducing the formation of a small amount of gum, and of causing a very limited amount of injury to bark tissue adjoining a wound when inserted into cuts on sound tissue, but it did not produce definite disease lesions. It has frequently been found associated with brown rot gummosis and appears to be capable of increasing the severity of this gummosis when associated with *Pythiacystis citrophthora* (as has previously been mentioned under "brown rot gummosis") but when acting alone, Fusarium appears to be of minor importance in gummosis. It should be stated, however, that Barrett[63] has found species of Fusarium constantly associated

[63] Barrett, J. T., Dry root rot. Calif. Citrus Inst., First Ann. Rept. 1919–1920, p. 157.

with the 'dry root rot' of Citrus trees in connection with which considerable gumming is frequently noted. Although the disease has not been reproduced by inoculation, this fungus is thought to be an important factor in the development of dry root rot.

ALTERNARIA

A species of Alternaria similar to *Alternaria citri* has very frequently been found in bark tissue associated with minor forms of gumming on lemon trees. Inoculation with pure cultures has shown that it may sometimes induce slight gum exudation and very slight injury to tissue adjacent to cuts into which spores were inserted. Small green immature navel oranges affected with black rot frequently show gum exudation at the navel cavity apparently due to the presence of *Alternaria citri*.

MISCELLANEOUS ORGANISMS

If, during the season for Citrus blast and black pit attack, the weather becomes warmer than usual, small drops of gum are apt to form at the edges of the twig lesions caused by the Citrus blast bacterium, *Bacterium citriputeale*, C. O. Smith. Slight gumming has been noted also on cuttings inoculated with this bacterium and held in moist chambers over a free water surface at constant temperatures of 80° and 93.4°F. (30° and 34°C.), but not at temperatures below this. Control punctures produce no gum. Large light-green lemon fruits also develop gum when inoculated with the same organism under the same conditions, but not in the uninoculated punctures.

It is probable that various other fungi are responsible for minor forms of gumming in Citrus. Observation has indicated that under certain conditions *Armillaria mellea*, *Schizophyllus commune* and other wood rotting fungi are minor agents in bringing about small gum exudations.

GUMMING ASSOCIATED WITH INSECT INJURIES

The injuries made by a number of insects are frequently followed by gumming, usually slight in amount. Small drops of gum may form on fruit at injuries produced by the orange tortrix (*Tortrix citrana*), and on small tree trunks and limbs from grasshopper, katydid and other insect injuries. Gumming has frequently been noted on twigs badly infested with the California red scale. To what extent this gumming may be due to secretions of the insects or to the entrance

of microörganisms at the time of injury is uncertain. Our negative results from mechanical injuries to Citrus kept sterile and free from chemical stimuli would indicate that this gumming was probably not due to the injury or wound in itself.

GUMMING ASSOCIATED WITH CHEMICAL STIMULI

Among the chemical stimuli that have been seen to result in gum formation occasionally in Citrus orchards may be mentioned: (1) liquid hydrocyanic acid spilled on the soil near the roots of trees; (2) hydrocyanic acid gas used in fumigation; (3) spray mixtures containing copper sulfate not properly neutralized with lime or containing other toxic substances; (4) a poison containing arsenic in contact with the bark.

Hydrocyanic acid coming in contact with a large main root usually causes the death of a strip of the bark on the trunk and even on the limbs and branches leading up from this portion of the trunk. This frequently results in considerable gumming adjacent to the killed strip and is sometimes mistaken for a definite gum disease. Under some conditions the shock produced by fumigation with hydrocyanic acid gas appears to be responsible for initiating gumming on the tree trunks of orange trees especially. The pressure in small gum pockets formed near the cambium produces small rifts in the bark through which the gum exudes in small drops, sometimes in numerous places on the trunk. Sometimes coils or strings of gum will be pushed out of small openings one to two weeks after fumigation. Such gumming is usually temporary and the places where the gum has formed quickly close up and fill with new tissue without noticeable injury to the tree.

Copper sulfate solution spilled on the soil over a root will kill strips of bark and result in gumming in much the same way as hydrocyanic acid.

Ant poisons containing arsenic when allowed to leak out of the containers frequently have the same effect.

PHYSICAL EFFECTS OF THE ENVIRONMENT

Physical effects do not appear to be as a rule more than contributing conditions for Citrus gumming under California conditions, other stimuli acting as the immediate cause.

Mechanical Injuries.—I have not been able to induce gum exudation on healthy Citrus trees by mechanical injuries alone, when the injured portions were kept clean and reasonably free from contamination with microörganisms or unusual chemical substances. The fol-

lowing kinds of wounds were made: vertical and horizontal cuts through the bark; augur holes with and without glass or wooden plugs; bruises by heavy and light blows of blacksmith's hammer; long horizontal and vertical slits through the bark; areas of bark cut away, etc. All such injuries kept clean, healed in the usual way without gumming. When purposely infected with *Botrytis cinerea* or other injurious fungi, however, gumming resulted.

Burning and Freezing.—Sunburning and freezing do not appear to be important factors in initiating gum formation directly, but they supply the conditions for the entrance of *Botrytis cinerea*, *Sclerotinia libertiana* or other fungi which, after becoming established in the injured tissue, may advance rapidly and induce gumming in tissue apparently sound. Freezing and sunburning often get credit for causing the gumming when they have merely opened up the way for the real causative agencies.

SUMMARY

For the sake of brevity this summary deals with average conditions. Allowance must therefore be made for variations in treatment for unusual or abnormal conditions. Consult the discussions in the text for more detailed statements.

Pythiacystis gummosis and *mal di gomma.*—Prevented by pulling the soil away from the base of the tree trunk until the tops of the first main roots are exposed; by keeping the soil next to the trunk from becoming excessively wet; by avoiding injuries to the bark; and by painting the trunks with fungicide such as Bordeaux paste or wash, lime-sulfur wash or a safe carbolineum. Treated when not too far gone, by cutting away the invaded killed bark, but not necessarily the outer gummous zone, and painting the wound with a suitable fungicide; by scraping away any outer layers of dead bark; by painting exposed portions of wood (after healing of edges begins) with benzine-asphalt paint or other suitable covering; by cutting back the tops on trees severely affected; by inarching or bridge grafting in certain cases.

Dry Root Rot.—Prevented by avoidance of excessive water and injuries; by providing good drainage and aeration to the roots. Lesions not too far advanced treated by cutting beyond visible margin of decay in the wood and bark and by disinfecting and painting.

Armillaria Root Rot.—Prevention of spreading obtained by eliminating the means of communication along the roots by trenches or

other methods. Treated if not too far along as in dry root rot. Fungus eliminated from soil by taking out all old roots or rotting wood and using carbon bisulphide.

Botrytis and Sclerotinia gummosis.—Prevented by the same methods as to soils, water, injuries, fungicides as in the previous disease. Treated by cutting out the dead bark to the wood and by scraping off only the outer bark beyond this, where the inner layer is not killed, and by painting with fungicide as in the previous disease.

Psorosis (scaly bark) of orange trees.—Methods of prevention not definitely known. Treated by scraping away the outer affected bark of lesions in the first and second stages, scraping lightly the bark not yet visibly affected to a distance of 6–8 inches beyond the lesion in each direction and applying Bordeaux paste or other suitable fungicides; by cutting out certain badly affected limbs altogether; by eliminating certain of the worst trees in the third stage of the disease or cutting them off below the diseased part where this is possible. Treatment must vary much according to the stage of the disease. (See discussion of various stages.)

Decorticosis (shell bark) of lemons.—Probably prevented in part by avoiding injuries to the trunk and keeping soil away from bud union. Treated, if very active, in beginning stages by scraping outer layers of bark over entire trunk and disinfecting as in psorosis.

Diplodia and Dothiorella gummosis and twig gumming.—Treated by eliminating the parts affected and by treating cuts with fungicide followed by paint where wounds are large.

Citrus blast.—Prevented in part by the use of windbreaks to avoid injuries to the foliage and twigs in winter and spring; by cultural methods conducive to good summer growth and a minimum of untimely fall growth. May be prevented in part also by spraying with Bordeaux not later than November 1st to 15th, a practice however not yet considered to be economically successful.

Exanthema.—Little is known as to its real cause, and no one definite method of prevention or control can be suggested for California conditions except to eliminate certain supposed contributing conditions where this is possible. (See previous discussion.)

Minor forms of gumming.—Not many of these are sufficiently important to require special attention either as to prevention or treatment. Where they are due to organisms most of the same principles apply as are given for the previous diseases. Some forms are dependent upon conditions that cannot be controlled but recovery often follows a change in the contributing conditions.

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